Climate Change in Asia and Brazil

The Role of Technology Transfer

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Foreword

The Asian Energy Institute has done an excellent job in putting together these ten country case-studies that focus on technology transfer in the energy sector with special emphasis on cogeneration and energy efficient lighting. The case-studies of the developing countries cover all major categories including the industrializing economies of the Republic of Korea and Thailand; the large-scale economies of Brazil, India, and China; and smaller country situations such as Bangladesh and Sri Lanka. This has provided a wide range of experiences in this area with relevant lessons for other countries.

Today, we can rightly say that developing countries firmly believe that the most economical energy supply source is energy saved through increased energy efficiency and conservation in the electric power and end-use sectors including industry, transport, and the residential and commercial sectors. This belief is being translated into action at two levels:

(i) first, at the energy policy level, where energy efficiency and conservation now form critical elements of national energy policies and strategies; and
(ii) second, at the operational level, where demonstration projects in energy efficiency and conservation are increasingly leading to large-scale national energy efficiency programmes with technical and financial support being provided by governments, and, sometimes, by national utilities themselves.

As pointed out in the Bangladesh case-study, the stages of technology transfer are 'Assessment–Acquisition–Adoption–Adaptation–Development–Diffusion'. The observation that in several smaller countries, there has been too much emphasis in the past on technology acquisition and too little on technology adoption and adaptation, is quite valid in many cases.

The potential for cogeneration in several of these countries is large. One interesting point that caught my attention was that while the sugar, textiles, and paper industries have large cogeneration potentials, these industries often have low to negative profits. As a result, the high initial capital costs of \$500–1000/kW installed capacity for oil/gas systems and \$1000–1500/kW for biomass/coal/wood systems cannot be met, especially since most of the costs have to be paid for in foreign exchange. It is a pity that, as a result, consumers continue to be saddled with higher operational costs. It is also interesting to note that while countries like the Republic of Korea and Thailand experience no problem on the technology side, other less technologically advanced developing countries have problems in technology selection and evaluation.

With respect to energy efficient lighting, the spread of fluorescent lamps is increasing. A few countries are starting large-scale bulb replacement programmes. The main problem preventing the rapid spread of fluorescent lamps seem to be their high initial cost, inadequate quality control which results in short lifetimes, the small size of the current market, and the lack of national energy performance standards. It is commendable that several countries are making valiant efforts to remove these obstacles.

Several of the articles in the book provide an excellent description of the evolution of energy and relevant legislative policies over the recent past. This background serves the reader well as one tries to put into perspective the actions taken, at both governmental and enterprise levels, to facilitate the spread of cogeneration and energy efficient lighting.

The Tata Energy Research Institute (TERI) has to be commended for putting together such an informative book, which should especially help decision makers as they attempt to increase national energy conservation and efficiency efforts.

James Gustave Speth
Administrator
United Nations Development Programme

Foreword

The Framework Convention on Climate Change requires all country parties to co-operate in the development, diffusion, and transfer of technologies and processes that control, reduce, or prevent greenhouse gas (GHG) emissions in all sectors, including energy, transport, industry, and waste management. Moreover, it requires that developed country parties take practical steps to facilitate the access of developing countries to environmentally sound technologies (ESTs) and know-how which would then enable them to implement the Convention. Furthermore, it enjoins upon the developed country parties to support the development of relevant endogenous capacities and technologies in the developing countries.

It has been almost two years since the vast majority of countries signed the Climate Convention, and accepted the far-reaching recommendations of Agenda 21 on action to promote sustainable development. The present collection of papers offers case-studies, from countries at various stages of industrialization, in developing, adapting, and promoting environmentally sound industrial technologies and products, notably in the power and lighting sectors, and in co-generation.

World-wide access to information on ESTs in the public domain has expanded over the recent past through clearing houses, networks, and the communication media. There has also been some progress in adoption, adaptation, and diffusion of private sector clean technologies, through joint ventures, direct investments, technical co-operation agreements, and various other means. Yet this progress is minuscule, in relation to the magnitude of the challenge of globally controlling and stabilizing GHG emissions, while accelerating and sustaining development, especially in the developing countries.

This book provides a comparative perspective on the challenges and difficulties encountered in this process, and the corresponding variety of the interventions needed. These include policy and institutional reform, regulations and their enforcement, incentive systems and pricing, concessionary financing, strengthening technical and managerial skills, awareness building and public education, and demand-side management. Some of the case-studies included in the collection provide pointers to the systemic approach also, which are needed to implement, successfully, a policy aimed at achieving a broad-based adaptation, use, and further development of ESTs and products acquired from abroad.

The case-studies contained in this book represent, individually and collectively, a useful contribution to industry, governments, non-governmental organizations, and international bodies engaged in advancing the implementation of the Climate Change Convention and Agenda 21. The Asian Energy Institute, the Tata Energy Research Institute, and their collaborating energy and environmental research institutions from Bangladesh, Brazil, China, India, Indonesia, Iran, Japan, Republic of Korea, Sri Lanka and Thailand, have rendered a service of practical value in making this instructive and interesting set of case-studies widely available. For this, practitioners and policy makers in the energy and environmental fields alike will indeed be thankful.

The empirical and analytical work presented in this collection should provide ideas and suggest avenues to integrate environmental management action in development planning. Moreover, its insights should help policy makers in developing ways and means to enable their countries fulfil their role in furthering international co-operation in environmental management. The case-studies should also help identify potential avenues of development co-operation, especially in regard to transfer of technology.

The Global Environment Facility (GEF) is now restructured and strengthened and its pilot phase of three years comes to an end in July 1994. GEF's mandate includes, *inter alia*, facilitating the transfer of ESTs to countries to enable them to play their part in the pursuit of global environmental objectives. GEF appreciates the work represented in this volume, and hopes that it would provide guidance to countries in developing practical avenues of international environmental co-operation through transfer, adaptation, and development of clean technology.

Mohamed El-Ashry
Chairman
Global Environment Facility

Preface

An overview of the contents of this volume, to say the least, is difficult and perhaps redundant, but a very inadequate attempt is made in this space to present the context in which this publication has been compiled. It may first be relevant to describe the background and evolution of the Asian Energy Institute (AEI), which is responsible for the research that has gone into this volume. It was in 1987 that the Asian Relations Commemorative Conference was held in New Delhi, forty years after the first Asian Relations Conference was convened by Mahatma Gandhi, in an effort to define and forge a new identity for Asia, a large part of which was emerging from the nightmares of colonial subjugation and devastation from a prolonged war in which several countries of this continent either participated directly or were drawn in indirectly. Asia has reached nowhere near the model of political cohesion that Europe has developed. Nor has Asia perfected the range and level of economic co-operation seen in several other parts of the world, but the 1987 Conference realistically identified some specific areas wherein co-operation could be initiated through collaborative activities. Energy was one such area in which there was a consensus on setting up a non-government institution for collaborative work. It was in response to this need that the AEI was established with its secretariat at the Tata Energy Research Institute (TERI).

Soon after this were initiated the preparations for the United Nations Conference on Environment and Development (UNCED), which required a vast amount of analysis and research on global environmental issues, for which the AEI and its constituent institutions were very well equipped. Technology and its linkages with development have a special relevance to Asia and its future. There is perhaps no other region in the world where technological development has been as rapid as in Asia. At the same time, there is no region where disparities are as stark in respect of the status of technologies employed. There are, at one end of the spectrum, countries like Japan which have established a position of leadership in a number of fields; while at the same time in parts of South Asia and countries like Cambodia and the Lao Republic, modern technology has not made any major impact on the lives of the people. Issues of technology transfer and use are, therefore, important not only for the recipients of technology, of which there are many in the region, but also the exporters of technology among which certainly Japan is a strong player.

The AEI has established a strong practice of working with a group in Brazil given the common professional interest in specific themes for research shared by the constituent institutes of the AEI and the institution in Brazil. In the initial phase of collaborative work carried out by the AEI the emphasis was on subjects related to the emissions of greenhouse gases (GHGs) and options for their mitigation. However, this work threw up not only the importance of technological issues that lie at the heart of mitigation of emissions of GHGs but also related them to the effectiveness of the Framework Convention on Climate Change. Even in the implementation of the Montreal Protocol, which presents a far less complex arena for concerted global action, technology and its transfer and adoption remain critical subjects that would determine the success and speed of implementation of the Protocol.

The material presented in this book focuses on specific country studies on technology transfer as they apply to two specific areas of technology upgradation, namely, improved lighting and industrial cogeneration. The first represents technological upgradation in perhaps the most commonly used electrical appliance in the world, and a device that is historically the very first with which people associate the use of electricity. The second which deals with the utilization of waste heat is an important component of upgrading the efficiency of energy use in a modern industrial system. Naturally, the choice of technology and the manner in which dissemination of know-how and equipment in both these areas take place differ substantially. It is also important to observe that the extent to which improved lighting can be disseminated is heavily dependent on the levels of income, the price of electric power and the initial cost of installing an improved lighting device to the consumer. On the other hand, cogeneration systems in a large number of situations in Asia are driven not only by costs and prices but also the regulatory and institutional arrangements by which the cogenerator can receive payments for supply of excess power from electric utilities and other possible customers. Legislation, in many parts of the world in recent years, generally aims at enabling cogenerators to sell excess power and receive reasonable prices that provide a powerful incentive for investments in such systems on a rational basis.

Technology transfer is, therefore, not merely an issue involving choices of technology and the apparent benefits that a society can derive and that an energy system could absorb in purely technical terms, but it is a direct function of institutional, economic, and cultural factors that in the ultimate analysis are dominant. Through a study of several countries and the coherent expression of opinions and presentation of analyses in differing contexts, this book aims to provide insights into how policies could be devised and mechanisms put in place by which the 'right' decisions on technology choices involving resource use efficiency and environmental protection are taken by consumers, producers, governments, and other actors. By no stretch of imagination can it be said that the two broad technology areas dealt with are representative of the wide spectrum of energy decisions that need to be taken to bring about rationalization and efficiency gains in energy systems round the world. But through the material presented in this book, certainly a vast field has been covered by which useful insights and knowledge for devising and implementing programmes in resource use efficiency improvements can be gained. Most importantly, this volume represents another significant step in cementing the relationship between the institutions that constitute the AEI, including the Associate Members, one of whom at least has contributed directly through a study pertaining to Brazil. It is intended that the future activities of the AEI carry this process logically several steps further in dealing with critical energy and environment issues facing humanity and the life support systems on this planet.

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The Tata Energy Research Institute (TERI), on behalf of the Asian Energy Institute (AEI), would like to thank the United States Agency for International Development, and the Danish International Development Agency for providing the support that enabled the study, the results of which are reported in this book. Thanks are also due to the participants of the workshop organized by AEI from 20–24 April 1992, for reviewing the 'Collaborative study on greenhouse gas emissions from Asia and Brazil and policy responses for their minimization', held at the Bellagio Study and Conference Center, Italy. At this workshop, the scope of the study reported in this book and the modalities for the same were finalized. The Rockefeller Foundation provided invaluable support for this workshop. The editors would also like to acknowledge the inputs provided by several colleagues at TERI in the preparations for the aforementioned workshop and for the production of this book. In particular, we would like to thank Ajay Mathur, Ligia Noronha, Prodipto Ghosh, Meena Srikumar, N C George, Rajeev Aggarwal, Anshu Sharma, and Deepa Prabhakar.

Editors

Introduction

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Rationale for the study

The potential threat of global warming and climate change is the greatest challenge ever faced collectively by mankind. The increasing concentrations of CO_2 and other greenhouse gases (GHGs) in the atmosphere could result in major climatic changes[1] with severe impacts on human activities such as agriculture and forests.

The rapid increase in global GHG emissions, and their pervasiveness across all human activities have spurred international political initiatives for their limitation. The agreements reached at the United Nations Conference on Environment and Development (UNCED), particularly the Framework Convention on Climate Change and Agenda 21, bring out the contours of current scientific and the political consensus. They also provide a global vision and an international framework for GHG emissions limitation.

The transfer of technology from the industrialized to the developing countries (DCs) is central to this vision. The Agenda 21 adopted at UNCED specifically noted that 'new and efficient technologies will be essential to increase the capabilities, in particular in developing countries, to achieve sustainable development, sustain the world's economy, protect the environment, and alleviate poverty and human suffering'.[2] The international political recognition now accorded to this idea highlights the intellectual appeal and the technological promise of technology transfer. The paradigm postulates that technology transfer would enable the developing countries to 'leapfrog' from traditional and high energy intensity economies to modern, low energy intensity economies in a short time.[3]

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[1] Global circulation models (GCMs) of the earth's atmosphere predict that current trends of GHG emissions would result in increasing the global average temperature (15 °C) by 1.3 to 2.3 °C in the next sixty years. This increase would probably enhance climate variability (Katz, Brown 1991). In a high CO_2 atmosphere, a general increase in the day-to-day variability of rainfall is predicted, with an increases in the frequency of heavy rain events. The number of tropical disturbances also increase, with little change in their average structure and intensity (Houghton, Callander, Varney, 1992).

[2] Chapter 34 in Agenda 21 (UNCED 1992).

[3] In recent years, Soete (1985), Goldemberg *et al.* (1987), and Goldemberg (1991) have examined this concept in a particularly powerful manner.

Typically, the rationale for the transfer of leading-edge energy technologies to the DCs has been the need to meet their high rates of energy demand growth, and to relax the constraints imposed by the limited availability of financial and natural resources. It has been argued that the introduction and deployment of high-efficiency energy technologies would both enhance energy supply and limit energy demand growth. This would, in principle, enable rapid economic development with a lower intensity of capital and primary energy use.

The imperatives of global warming have provided a new urgency to technology transfer; and rapid energy efficiency enhancement is viewed as the primary strategy for limiting GHG emissions. An assessment of the current and projected GHG emissions in seven Asian countries[4] and Brazil, carried out by member institutions of Asian Energy Institute (AEI)[5] in 1990/91, indicated that emissions in all countries would more than double by 2000 AD (AEI 1991). A subsequent study of the GHG emissions limitation strategies indicated that energy efficiency improvements were, by far, the most cost-effective means for limiting emissions (AEI 1992).

The results of the AEI study on GHG emissions limitation strategies were discussed at a meeting held at the Rockefeller Study and Conference Center in Bellagio, Italy, from the 21–24 April 1992. The energy efficiency improvements in the mitigation studies were assessed from the perspective of their achievability. Their introduction and deployment were evaluated on the basis of the 'best-available technological practice'; the extent of commercial experience with such technologies; the infrastructure in the DCs to support their optimal performance; and the conduciveness of the macroeconomic policy framework and the legal and institutional structure to support rapid technological change.

The diversity of experience relating to technological change and to the 'effectiveness' of technology transfer indicated the broad range of realistically achievable energy efficiency gains. The importance of country-specific experiences in evaluating carbon emissions limitation through energy technology upgradation leads to the design of this collaborative study.

The major objective of this collaborative study is to understand the nature of the process of technological change, and the role of technology transfer in enabling this kind of change. Specific examples of technological change are studied to illustrate the process—the experience with the deployment of cogeneration and efficient lighting technologies has been studied in all the participating countries to compare and contrast the process.

In the next section, the experiences regarding the effectiveness of the technology transfer process over the past few decades are examined. The empirical evidence is then analysed to define the scope of the present study, and to develop an analytic framework.

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[4] Bangladesh, China, India, Japan, Korea, Sri Lanka, and Thailand.

[5] AEI is a network of twelve research institutions in Asia and one in Brazil. All the institutions focus on energy issues within the larger perspective of economic development and environmental sustainability. Member institutions collaborate on common projects, thus providing a structured, but richly varied, insight into the energy sector of DCs.

Empirical evidence

The political economy of technology transfer

Transfer of technology from the industrialized countries (ICs) to the DCs accounts for a large fraction of the stock of technological knowledge and of capital plant and equipment in the latter group of countries. In recent years, the fraction of indigenous capital plant and equipment has been growing rather rapidly in almost all DCs. The growth of indigenous technological knowledge has, however, been less satisfactory. With the exception of the newly industrialized countries of East Asia, and partly that of Brazil, the DCs continue to be trapped in a technology-import spiral. Technologies are imported; put into production; and then as productivity is unable to keep pace with international competition, new and advanced technologies are again imported. Consequently, technology transfer costs always remain as a significant fraction of production costs, and productivity trends are never near the international frontier.

The ineffectiveness of technology transfer in stimulating indigenous technological dynamism and in creating local technological capabilities is largely because of the reasons examined below.

(i) *Imported technologies tend to preserve and strengthen the vested interests of the elites in the dual economies of the DCs.*

Technological change and technology upgradation are high-cost processes undertaken (everywhere) by enterprises and groups which have access to economic surplus and the motivation to enhance this surplus.[6] As a result, these processes are not politically and economically neutral, but a 'reflection of the hierarchical and authoritarian class relations of industrialist capitalist production' (Dickson 1975). These processes continue in the ICs because of the simultaneous development of political systems that have sought to temper this class division through the creation of 'national bargains'.[7] In these countries, a bargain has been struck (and a new social contract forged) among the individual, the society (government), and the industrial corporations. The latter invest in technological development and harvest the yields of greater productivity, but provide a significant share of the profits to individuals, both through salaries and through societal welfare mechanisms. The government, in turn, does not interfere in management prerogatives, but invests in the education of children for gainful employment and regulates the harmful side effects of the economic processes, such as public health, safety, and the environment. A comparative bargain is largely lacking in DCs because of deep and

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[6] Rosenberg, Birdzell (1986) argue that the 'West's system of growth required a social class with the capacity to effect innovations, with incentives or motives for innovation, with a source of ideas for innovation, and with immunity to interference by the formidable social forces opposed to change, growth and innovation'.

[7] Reich (1991) brings out the implicit national bargain in the US that accepted the permanence of the American core corporation in return for prosperity. The continued profitability of these corporations became one of primary responsibilities of the US government. The argument can be extended to the western democracies, and to the Organization for Economic Co-operation and Developing (OECD) as well.

rigid class structures. Consequently, contracts are between dominant social classes, rather than just between classes.[8] As a result, technology transfer (and resulting gains in productivity and profitability) has often served to further the interests of the dominant classes in enhancing control over production, preserving low wages, and maintaining industrial peace. This is a significant departure from the ICs where the national bargain has evolved towards a larger sharing of profits with the workforce and the government. Technology transfer has therefore, often, been utilized by the dominant classes in the DCs to minimize investment in local technological development and in physical and human infrastructure. Blueprints, plants, and equipment are acquired for the production of goods and services required by these classes, without any long-term commitment or technological strategy. This leads to the import of inappropriate technologies and to their sub-optimal utilization.

(ii) *Imported technologies are inappropriate relative to the local factor-mix.*
The political economy of technology transfer delinks the national economy from the nature of the technology transferred. Blueprints, plants, and equipment that have evolved in ICs are implanted in DCs where the factor-mix is quite different. The two factors, where the greatest mismatch occurs, are capital and labour quality. The scarcity of capital in DCs leads to real interest rates that are two to four per cent higher than in the ICs. Consequently, plant and equipment located in DCs, *ceteris paribus*, costs more than in the ICs. Similarly, enhanced labour skills and expertise are now playing a major role in exploiting the potential for technological productivity increases in the ICs. However, the resources devoted to upgrading worker skills remain inadequate in most DC enterprises. They also form an insignificant share of the costs of technology transfer. This sub-optimal investment leads to the promised productivity increases not being fulfilled.

(iii) *Existing international financial mechanisms discourage long-term relationships between technology vendors and buyers.*
Existing institutions and mechanisms have been unable to support the level and quality of technology transfer required for sustainable development. This stems out of the speculative and 'anarchic' nature of international capital which seeks short-term profit maximization, quite in contrast to the long-term stability needs of industrial capital.[9] This finance–industry

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[8] The contracts between the ruling (or elite) class in India are brought out and discussed by Bardhan (1984). Three social classes (representing industry, white collar workers, and rich farmers) have effectively expropriated all the gains of the development process, leaving the majority of the population almost stagnant. Limited mobility between classes has resulted in a blurring of social and functional classes in India; the majority of population being outside any functional class.

[9] Amadeo, Banuri (1991) point out that the symbiotic relationship between industry and finance can break down on occasion. In such cases, finance becomes a source of macroeconomic instability. Consequently, all governments place restrictions on the mobility of local investment capital within their borders. However, at the international level, with the breaking down of the Bretton Woods system, capital flows seem to have a dominating influence on the conditions under which production and trade take place.

('Keynsian') conflict played out at the international level is particularly debilitating for DCs for two reasons. The first is that international capital (hard currency), is often the keystone to technology transfer agreements, and its restrictiveness inhibits the scope and duration of these agreements. The second is the effective real interest rates faced by DCs (i.e., the difference between international credit interest rates, say the London inter-bank offer rate, and the rate of change of prices of exports from DCs) have been increasing dramatically.[10] At the same time, the level of concessional lending (official development assistance as a fraction of the gross domestic product (GDP) has decreased consistently, and fallen in real terms during the nineties in most OECD countries (World Bank 1994). This has reduced the 'programmatic' rubric of international capital availability in favour of increased 'projectization'. As a result, technology transfer flows tend to be ad hoc, and reduce cumulative experience and learning.

The consequences for climate change limitation strategies

As a result of these institutionalized biases, technology transfer has had a limited effect on enhancing the technological productivity of the DCs. In the present debate on the role of technology transfer in limiting climate change, the two outcomes, listed below, of the historical technology transfer process are particularly relevant.

(i) ***Technologies never reach the design efficiencies***

Much of the technology imported into developing countries never reaches its design capacity, and its performance deteriorates significantly over its operational life. The evidence in the energy and other sectors in the DCs shows that, in practice, the operating performance of many imported technologies does not, even initially, reach its potential as reflected in design specifications, and subsequently follows a trajectory that at best remains stagnant and, at worst, shows a considerable deterioration in performance. The learning experience with the new sizes of coal-based thermal power generating units in India and in Britain is shown in Figure 1. The average availability of the units increased initially in both countries, and stabilized ten years after the installation of the first units. However, average availability at any time after the first-unit installation was always less in India than in Britain, and the stabilized value was about 10% less in India (at about 77%) than in Britain (at about 90%). This finding is reflected in the evaluation of many aided projects, particularly in the power sector, which shows that the performance of individual projects deteriorates over time because of inadequacies in the systems in which they have to operate. The World Bank has concluded that 'the justification of projects depends in large measure on sustaining the sector over the physical life

[10] Hughes, Singh (1991) note that the effective real interest rate on the DC floating rate debt increased from −11.8% in 1977 to 15.9% in 1983. Consequently, there are net capital outflows from many DCs (mainly in Latin America) to the ICs.

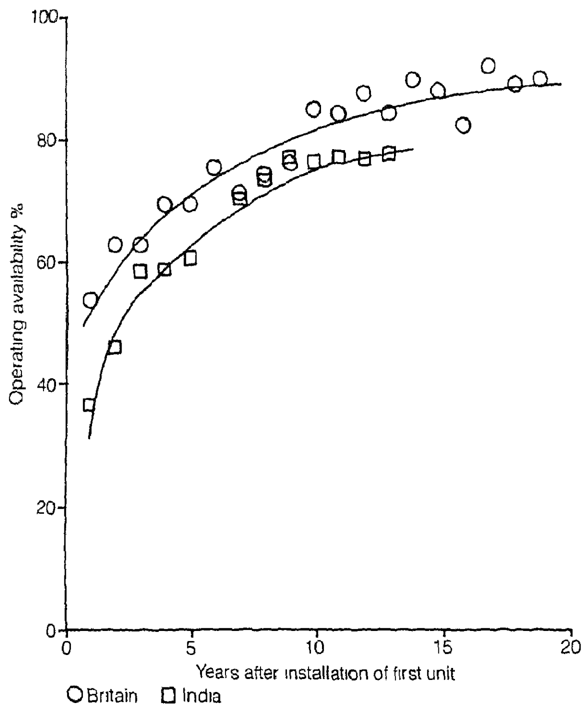


Figure 1. The learning curves for average unit availability of new sizes of coal-based thermal power generating units introduced in India (200 MW units) and in Britain (600 MW units)
Source. Mathur, Bhandari (1993)

of the assets. For many utilities, this is a questionable prospect given the performance over the past two decades' (World Bank 1989).

(ii) ***The market demand for efficient technologies is limited***
The dynamics of DC markets are still controlled by the burgeoning demand for industrial goods; the pull of enhanced quality and increased productivity (including energy) is still relatively small. Consequently, in these non-equilibrium markets, extremely wide technological levels co-exist. The economic buying power for high-efficiency goods is limited; so is the politco-economic motivation for large-scale technological upgradation. This implies that the vast efficiency gaps that seek to be bridged through technology transfer are largely illusory. Efficiency enhancing technology transfer would be limited to dynamic enterprises that are already on productivity increasing trajectories, and to the richest class of consumers.

The world community, therefore, faces a formidable task if it is to effectively transfer technology to improve the rational use of energy. It is difficult to escape the conclusion that in the

final analysis many of the barriers stem significantly from a lack of finance on the part of the technology buyer. The quantity of technology required is constrained by the lack of industrial finance and by consumer poverty. This shortage is the result of both the absolute shortage of resources, which essentially characterize DCs, and the difficulties experienced in getting financial institutions to support such activities (Barnett 1994). This suggests important initial conclusions: (i) effectiveness of technology transfer in enhancing energy efficiency will require the availability of much larger financial resources; (ii) deeper and longer technology transfer agreements are essential; and (iii) restructuring of the financial flow mechanisms is required. This fundamentally affects what one expects of technology transfer programmes, and what technology should be transferred.

Scope of the study

The current evaluation of the transfer of technology sharply brings out the need to centre the analytic focus of technology transfer strategies on the tasks that the technology buyer must perform in order to utilize imported equipment and skills. It also highlights the specific effectiveness of the technology transfer experience. The current study, therefore, focuses on two specific technologies (cogeneration and efficient lighting) and on national experiences relating to the transfer of these technologies in the perspective of (i) national technology transfer policies; (ii) physical, human, and institutional infrastructure; and (iii) technological change experience in the countries.

Analytical framework

The process of technological change has attracted much attention in recent years.[11] Technology, and the ability to master it, has been recognized as a part of the competitive process and can be used both to win markets and as a defence against competitors. Indeed, the capacity to manage these processes or technical change to advance increasingly defines the divide between ICs and DCs (OECD 1991).

The national studies in this volume analyse technology acquisition and absorption in the case of cogeneration and efficient lighting technologies. When the source of change is the transfer of technology from abroad, the effectiveness of the transfer is assessed in terms of the capacities to fully 'master' that technology, adapt it to local conditions, improve it over time, and use these capacities to generate technical change in the future.

[11] See, for example, the seminal works of Nelson, Winter (1982) and Dosi (1984). Technical change literature related to DCs has been critically assessed by Bell, Pavitt (1992). Bell (1990) provides an insight on energy efficiency-enhancing technological change in DCs and on related issues in technology transfer.

The institutional mechanisms that impinge on this capacity development are evaluated. These include the financial, legal, and policy frameworks, as well as the availability and quality of human resources. The importance of the role of the public R & D institutions, and enterprises in the transfer of technology is looked into.

Finally, the international financial mechanisms that are involved are identified and evaluated. The relationships between the types of foreign investment (direct foreign investment, licensing, etc.) and the degree of technology transfer are brought out.

REFERENCES

1 AEI. 1991. *Global Warming: Mitigation Strategies and Perspectives from Asia and Brazil. In* Pachauri R K, Behl A (eds). New Delhi: Asian Energy Institute/Tata McGraw Hill Publishing Co.

2 AEI. 1992. *Global Warming: Collaborative Study on Strategies to Limit CO_2 Emissions from in Asia and Brazil. In* Pachauri R K, Bhandari P (eds). New Delhi: Asian Energy Institute/Tata McGraw Hill Publishing Co.

3 Amadeo E F, Banuri T. 1991. 'Policy, governance, and the management of conflict'. In Banuri T (ed.) *Economic Liberalization: No Panacea.* Oxford: Clarendon Press. 29–55.

4 Bardhan P. 1984. *The Political Economy of Development in India.* Oxford: Basil Blackwell.

5 Barnett A. 1994. 'Knowledge transfer and developing countries: the tasks for science and technology in the global perspective 2010'. *Technology Transfer* **21**(1): 2-12.

6 Bell M. 1990. *Continuing Industrialisation, Climate Change and International Technology Transfer.* Brighton: University of Sussex.

7 Bell M, Pavitt K. 1992. '*National Capacities for Technological Accumulation: Evidence and Implications for Developing Countries*': Proceedings of the World Bank Annual Conference on Development Economics (1992). Washington, DC: International Bank of Reconstruction and Development.

8 Dickson D. 1975. *The Politics of Alternative Technology.* New York: Universe Books.

9 Dosi G. 1984. *Technical Change and Industrial Transformation.* London: MacMillan.

10 Goldemberg J, Johansson T B, Reddy A K, Williams R H. 1987. *Energy for a Sustainable World.* New Delhi: Wiley Eastern.

11 Goldemberg J. 1991. Leap-frogging: a new energy policy for developing countries. *The Journal of the World Energy Council*: December.

12 Houghton J T, Callander B A, Varney S K. 1992. *Climate Change 1992.* Cambridge: Cambridge University Press.

13 Hughes A, Singh A. 1991. 'The world economic slowdown and the Asian and Latin American economies: a comparative analysis of economic structure, policy and performance'. In Banuri T (ed.), *Economic Liberalization: No Panacea.* Oxford: Clarendon Press. 57–97.

14 Katz R W, Brown B G. 1991. Extreme events in a changing climate: Variability is more important than averages. *Climatic Change.*

15 Mathur A, Bhandari P. 1993. Options and strategies to limit CO_2 emissions from India. *In* Achanta A (ed.). *Climate Change Agenda.* New Delhi: Tata Energy Research Institute.

16 Nelson R, Winter S. 1982. *An Evolutionary Theory of Economic Change.* Cambridge: Belknap Press.

17 OECD. 1991. *Managing Technological Change in Less Advanced Developing Countries.* Reference 43 91 03 1. Paris: Organization for Economic Co-operation and Development.

18 Reich R B. 1991. *The Work of Nations.* London: Simon & Schuster.

19 Rosenberg N, Birdzell L E (Jr). 1986. *How the West Grew Rich.* USA: Basic Books.

20 Soete L. 1985. 'International diffusion of technology, industrial development and technological leapfrogging', *World Development* 13(3).

21 UNCED. 1992. Agenda 21. Geneva: United Nations

22 World Bank. 1989. A review of world bank lending for electric power. Working Paper Series **107**. Washington, DC: International Bank for Reconstruction and Development.

23 World Bank. 1994. *World Development Report 1994.* Oxford: Oxford University Press.

Technology transfer in the Bangladesh context

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1 Introduction

Technology, which was once referred to as a 'residual' factor for development, is now accepted universally as the 'engine' of growth for any economy—developed and developing. The four basic components of technology, which contribute equally to the development goals of any economy, have been outlined below (UN ESCAP 1989).

(i) *Technoware*—production tools, machines, etc., which are the object embodied form of technology.
(ii) *Humanware*—production skills, innovativeness, creativity, etc., which constitute the human embodied form of the technology.
(iii) *Infoware*—production facts recorded as theories, designs, blueprints, etc., which constitute the document embodied accumulated knowledge or information.
(iv) *Orgaware*—production arrangement linkages, which constitute the organizational framework within which the technology needs to operate to raise productivity.

These components of technology are complementary and interdependent. The complementary nature of the components can be explained as given below.

- *Technoware* is the core of any transformation. It is developed, installed, and operated by *Humanware*.
- *Humanware* is the key element of any resource transformation operation and it is in turn guided by *Infoware*.
- *Infoware* is generated by *Humanware* and utilized for decision making and operation of *Technoware*.
- *Orgaware* acquires and controls *Infoware*, *Humanware*, and *Technoware* to effect any resource transformation operation.

It has been observed that those developing countries, which have made extraordinary economic progress in the last two decades, had introduced the right policy instruments which ensure the development and promotion of all the four components of technology. These countries achieved an effective technology transfer and now possess substantial technological capability.

2 Technology transfer

Although the term 'technology transfer' gives the impression of a donor and a recipient, in reality, the situation is quite different. Technology has a price, and must be paid for in some form or other. Technology transfer is the importation of technology based on mutuality of interest. A meaningful and effective technology transfer would therefore involve certain steps—technology assessment, acquisition, adoption, adaptation and development, and diffusion.

Successful technology transfer occurs only when all the components of technology, as discussed in the previous section, are considered in detail in these steps. As discussed in subsequent sections, policy planners, scientists, and technologists in Bangladesh have, in most cases, concentrated on the second step. As a result, technology transfer activities were not successful. Moreover, the adaptation and development did not take place to any noticeable degree. All the technology that is present in the country has been acquired from abroad and the minimum training requirement for normal operation and routine maintenance has been met. Technical assessment of large projects is being carried out on the behalf of Bangladesh by expatriate consultants engaged for the job and paid for by the donor agencies out of the aid allocation.

3 Barriers to technology transfer in Bangladesh

3.1 Technology policy inadequacies

Policy studies and initiatives for technology transfer in Bangladesh have remained limited to declarations of intent without the operational mechanism. The implementing agencies, in most cases, lack the manpower and organizational capability to comprehend the implications of proper technology transfer and are unable to carry out policy directives in this regard. In some cases, only a small part of the total transfer process has been catered to, resulting in stunted growth.

The first attempt towards the formulation of a state policy for science and technology was made in 1980 and 1985 when a comprehensive National Science and Technology Policy (NSTP) document was prepared and circulated. A section of the NSTP deals with 'establishment of a national capability for development of indigenous technology and attainment of a national capacity for the assessment, selection, acquisition, adoption, and adaptation of foreign technology'. In this connection, a committee named the Consultative Committee on Transfer of Technology was formed in 1987 for the implementation of NSTP. This committee had suggested certain action programmes and indicated the institutional arrangements for their implementation. However, nothing tangible has been achieved.

3.2 Human resources and R & D

High literacy rate and skilled manpower are pre-requisites for technological advancement. In Bangladesh, the literacy rate of those 15 years and above is 29.2% only. In addition, the emphasis

historically, has been towards liberal arts subjects rather than science and technical subjects. As a result, the technical education base is weak.

As already mentioned, the bulk of the technology in the country is imported. There has not been any concerted effort for the building up of institutions that could be involved with studies/research on the assessment and absorption of imported technology. The various steps necessary in this connection are the identification and evaluation of technological alternatives, regulation of technology importation, engineering design, technology adaptation, experimenting in existing plants, etc.

With the exception of some areas in the agricultural sector, most organizations lack organized and well-planned research management systems. Research efforts are fragmented, unco-ordinated, and generally not related to long-term development objectives. Presently R & D organizations suffer from a shortage of competent manpower. Severe 'brain drain', resulting from poor funding and lack of proper service conditions in R & D institutions of the country, has in recent times caused a dearth of competent scientists, engineers, and other skilled personnel. In addition, local R & D institutions lack adequate documentation and information facilities and, except for the agricultural sector, there exists no organized information network in the country.

3.3 The impact of external assistance

In the absence of a comprehensive technology-based development policy with cross-sectoral considerations as exemplified by the existing situation in Bangladesh, it becomes difficult for funding agencies to identify the technological goals of a developing country.

New and varied technologies of different origins are being transplanted without modification. Technology transfer is confined to the installation of the imported plant with the help of expatriates, training of engineers/technologists/technicians in a similar plant abroad, and the supply of a set of operating/instruction manuals (often inadequate) and drawings Such transfer elements amount to a 'static' mode of technology transfer and prevents the chances of a 'dynamic' transfer of technology, which is necessary to raise the technological level of the country for undertaking innovative ventures in a competitive world.

As is common in many developing countries, 'projects' are initiated and implemented which benefit some trans-national companies and their agents. Thus, one hears of 'agency-oriented projects' or 'donor-oriented projects' or even projects designed to profit a given supplier of hardware and/or software. Furthermore, many projects have multiple donors. The spares and raw materials then become so varied that local input becomes difficult due to the small size of the demand.

4 Cogeneration and technology transfer: a case-study

4.1 The electric power sector

The Power Development Board (PDB) is the public sector agency that is responsible for the develop-

ment, production, and management of the power sub-sector in Bangladesh. The installed generation capacity of PDB (June 1990) is 2179 MW of which 1374 MW is suitable for base load operation and the remaining 805 MW for intermediate and peak load generation (GOB 1991a). The fuel mix for the 7732 GWh of electricity generated in 1990 was:

- hydro—884 GWh (11.43%);
- natural gas—6515 GWh (84.26%); and
- petroleum—333 GWh (4.31%).

PDB's power plants consist of both new and old plants. The older plants (some over 25 years) are prone to frequent breakdown. Of the total generation capacity of 2179 MW, the dependable capability is only about 1479 MW, compared to a peak demand of approximately 1600 MW. Thus, the power supply remains unreliable. The thermal efficiency of PDB's generating plants (mostly steam thermal units) is low (approximately 25%), and the technical and non-technical losses in power distribution amount to a staggering 40%. These factors are responsible for the poor performance of PDB.

4.2 Participation of the private sector in the power industry (electric power)

Before the establishment of PDB, private companies operated and managed electric utility services. At present, the power sector in Bangladesh is totally controlled by PDB, with the exception of a few stand-by generators in some industries. The Fourth Five Year Plan (1990–1995) has laid emphasis on private sector participation on a build, operate, and transfer basis for power generation. However, appropriate strategies and guidelines are yet to be worked out for private sector participation. A clearly stated policy to encourage local/foreign private investment is required. Privately owned and managed power generation units should be able to meet the growing demand for power and be, at the same time, more efficient and reliable than PDB.

4.3 Cogeneration technology

In Bangladesh, cogeneration provides the bulk of the electric power for the fertilizer, paper, and sugar industries. Additionally, some industries, such as cement, have self-generation capabilities. There exists further potential for the utilization of cogeneration in six industry sectors:

- paper and allied products;
- tea;
- food;
- jute;
- textiles; and
- other manufacturing industries.

Table 1 (GOB 1986) shows the economic potential for cogeneration in these sectors. The industries which have the greatest potential for cogeneration (jute and textiles) are also those which have

significant electricity consumption. This analysis shows that a total savings of 5.15 PJ could be realized through the initiation of a national industries cogeneration programme. This represents approximately 12% of the fossil fuel consumption for power generation.

Preliminary economic analysis of various cogeneration systems showed, through examination of the detailed energy consumption patterns by industry, that gas engines with waste heat recovery (hot air, steam, and/or hot water) and gas turbines with heat recovery steam generators were the most viable and that, for these cogeneration systems, the minimum economic size for a base load unit is 500 kW electric and for a unit designed to deliver peak demand is 1000 kW electric. Thus, the economic potential for cogeneration, as given in Table 1, was determined for plants which have power demand greater than these values. The total investment requirement for a national cogeneration programme was estimated to be US $76 million in 1984. Implementation of industrial cogeneration systems would have a major impact on reducing energy use. The economic incentives of cogeneration in existing industries is even greater in those cases where new boilers need to be constructed or old boilers need replacement. The poor reliability of power has made self-generation both cost-effective and energy efficient. Cogeneration can potentially save significant quantities of energy and also reduce the burden on PDB's overstretched generation capacity.

A number of major policy issues need to be resolved before cogeneration will be feasible for general implementation in Bangladesh. Cogeneration will require a concerted government effort to effect significant implementation and is at present given medium priority. The immediate focus should be on resolving the policy issues, then (assuming the policy issues are resolved) on demonstration projects and initial implementation, and in the longer term, a full implementation effort should be pursued.

4.4 Specific examples of cogeneration potential

The cogeneration potential and investment requirements along with the profitability analysis of three industries have been recently studied by the Energy Monitoring Unit of the Ministry of Energy and

Table 1. The economic potential for cogeneration

Industry	Electricity consumed at present (PJ)	Electricity which can be displaced under cogeneration (PJ)
Paper and allied products	0.14	0.09
Tea	0.50	0.04
Food	2.02	0.47
Jute	3.54	2.27
Textiles	2.60	1.67
Other industries	2.23	0.61
Total	11.03	5.15

Table 2. Cogeneration potential of three local industries

Cogeneration potential	Jute	Textile	Combined (jute, tea, textile)
Annual power saved (10^6 kWh)	2.24	8.63	9.82
Fuel to engine (GJ)	24 321.00	89 977.00	102 435.00
Steam (kg/hr)	196.00	1020.00	1171.00
Heat recovered from exhaust and jacket cooking (GJ)	2061.00	12 968.00	17 356.00
Annual energy saving (gas to boiler) (GJ)	2748.00	17 251.00	21 696.00
Net annual income (1992—1000 $)	72.00	305.00	324.00
Investment (1992—1000 $)	242.00	1222.00	1305.00
IRR (%)	28.90	21.80	23.80
Payback period (years)	3.39	4.35	4.03
Technology			
Generator capacity (MW)	440.00	960.00 × 2	900.00 × 2
Boiler capacity (kg/hr)	245.00	2000.00	2000.00

Mineral Resources (GOB 1991b). The summary of these studies is presented in Table 2. The industries are jute, textile, and a combination of jute, textile, and tea. All these projects show a good internal rate of return (IRR) and small payback periods. Cogeneration and captive power generation can, therefore, save a considerable amount of energy and thus lead to lower carbon emissions.

The breakdown of the investment requirement for one of the projects is shown in Table 3. As is evident, the obvious drawback of cogeneration projects is the high initial investment required for the latest state-of-the-art cogeneration technology. Furthermore, over 85% of the investment would require foreign currency. The technology suggested in all cases is gas-fired reciprocating engines and

Table 3. Breakdown of investment requirement for the textile industry (1992 $ = 40 taka)

Technology	Lakh taka
Engine/alternator sets	275.00
Waste heat recovery boilers	40.00
Civil and building works	16.00
Mechanical installation	5.00
Gas installation	5.00
Electrical installation	53.00
Spares	15.00
Engineering design/project management	5.00
Import duties and taxes	50.00
Monitoring and bank costs	9.58
Contingencies	15.00
Total	488.58

waste heat boilers. At present, it is not possible for Bangladesh to develop its own technology for the production of efficient generators. Waste heat boilers may be produced locally if effective technology transfer can be achieved. Soft loans must be provided to help local industries in acquiring the state-of-the-art power generation technology. In fact, international financial institutions, such as the World Bank, have agreed to finance cogeneration projects, which is a positive step in the technology transfer process. However, sectors where cogeneration potential is high, namely jute and textile, are either incurring losses or are only marginally profitable. The credit worthiness of these industries is not favourable. This prevents local commercial banks from disbursing soft loans obtained from the World Bank. Therefore, despite the good viability of such projects as indicated in Table 2 in terms of saving both money and energy, little has been achieved towards the actual implementation of cogeneration projects.

References

1 GOB. 1986. National Industry Energy Conservation/Substitution Program. Dhaka: Government of Bangladesh, Ministry of Energy and Mineral Resources.
2 GOB. 1991a. Report of the Energy Task Force on energy development planning in Bangladesh. Dhaka: Government of Bangladesh, Ministry of Planning.
3 GOB. 1991b. Appraisal reports of various industries for potential cogeneration. Dhaka: Government of Bangladesh, Energy Monitoring Unit.
4 UN ESCAP. 1989. A framework for technology-based development: outputs of the Technology Atlas Project: 1. New York: United Nations Economic and Social Commission for Asia and Pacific.

Technology transfer and absorption in developing countries: a case-study of lighting and cogeneration in Brazil

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1 Case-study of efficient lighting systems in Brazil

1.1 Introduction

This section is about the transfer and absorption of a set of new technologies for more energy efficient lighting. It analyses the barriers to the market penetration of groups of energy efficient technologies which are, in principle, cost-effective. The rapid diffusion of these technologies is of special interest to developing countries. This is due to their severe financial and environmental constraints on supplying a growing energy service demand, which can be relieved by technology transfer. In broader terms, energy efficient technologies and systems can add new degrees of freedom in resolving trade-offs between environmental and development imperatives. However, these technologies (and the 'software' and 'systems' associated with them) are mostly not penetrating their markets rapidly in developing countries, even in situations where they offer very high returns, as is the case with several lighting technologies in Brazil. Important barriers hinder the penetration of cost-effective new technologies. In order to obtain a comparative international perspective, the Asian Energy Institute is co-ordinating parallel analyses in developing countries. This paper is one such case. A discrete set of technologies have been chosen in each country.

'Technology', as understood in this work, includes not only the equipment 'hardware', but the 'software' needed to use it as well—skills, institutions, information, and 'culture'. This 'software' is receiving growing attention among those concerned with the diffusion of energy efficient technologies. The emphasis here is on technology acquisition and absorption rather than on development or even adaptation. This is partly a consequence of the characteristics of the market, for supplying lighting equipments, which is dominated by a small number of multinationals (see Section 1.2). But it also reflects a wider belief that most technologies of interest already exist and are proven. The main problem is their introduction and penetration in the markets of Brazil and other developing countries.

This section details the case of electric lighting technology. As in many developing countries, kerosene is widely used for lighting in rural areas due to the lack of access to electricity. However, the authors have no experience with non-electric artificial lighting sources. It is to be hoped that these

lighting sources will be treated in the parallel papers from countries where residential kerosene consumption is relatively more significant than in Brazil. Here it accounts for only 0.2% of oil consumption, and the consumption has fallen to almost 60% since 1980.

1.2 Context for lighting technology transfer and absorption in Brazil

The future evolution of lighting technology and its application is a question of strategic importance for policy towards power sector expansion. As an end-use, lighting accounts for about 15% of electricity consumption, but its importance for near term policy on technology transfer and energy efficiency improvement is greater. First, the technical potential for efficiency improvement in basic equipment is very large, perhaps the largest of any end-use. There are many cases where the energy consumption of the basic lamp assemblies supplying the same quantity and similar quality of light falls by half or more. Furthermore, this technology is commercially proven. Second, the design of the use of these lamp assemblies offers large scope for improvement. For example, most architects in Brazil appear to have only a rudimentary understanding of lighting. The solutions adopted often involve unnecessarily high maintenance and operating costs. Moreover, the results are impressive rather than functional. There is, however, ample scope to address the factors leading to this situation. In this sense, lighting also lends itself, like other areas, to energy efficiency improvement—the possibility of significant gains from rethinking the basic 'process' of producing a product, the product itself, and how to use the product in a context of financial and environmental restrictions.

The third point is that most of the lighting equipment has, on average, a useful life, though a relatively short one when compared to most investments by consumers, which significantly influences energy consumption. Conventional bulbs and lamps last for a very short while, sometimes less than one year. While the lighting system is designed to last substantially longer than the lamp, major changes in lamp and other technologies, combined with new user perceptions of lighting needs and costs, can, in principle, lead relatively quickly to notable changes in the stock of equipment.

These points and the sheer visibility of lighting make this an interesting area for energy efficiency programmes to emphasize in their early phase. A lighting programme can show results which increase consumers' awareness of energy efficiency in general. Brazil's early modest efforts at electricity conservation have, in fact, given considerable emphasis to lighting.

Some individual utilities have had programmes of electricity conservation for ten years. A national programme, called the Electricity Conservation Programme (PROCEL), was launched in 1986 to deal comprehensively with barriers to improving energy efficiency (Geller, Moreira 1992). Considerable attention was given to defining new technologies of interest, labelling certain appliances, energy audits, and the promotion of more efficient public illumination. A few results were achieved, but the programme then suffered cutbacks. In 1990, a special high-level council was formed to help orient conservation efforts in general and to give them political impetus. This council, the Executive Group for Energy Rationalization (GERE), has achieved some concrete results, especially regarding taxation and import duties (GERE 1992). The council has recently become less active, but, in compensation, PROCEL has again become more dynamic.

The supply of lighting equipment and systems is entirely in the private sector. At the base of this industry are the manufacturers of lamps. This segment is dominated by a small number of multinationals—Philips, Silvania, General Electric (GE), and Osram—and is definitely very cartelized within Brazil. The cartel's market is mostly protected against imports, as is the case with most Brazilian industrial cartels. This combination of cartelization and protection can create problems for introducing improved technology. For example, PROCEL launched a programme to stimulate the installation of more efficient public illumination. This programme entailed free marketing for the manufacturers of relevant equipment. It would help them increase the volume of sales in the short and medium term, thus reducing unit costs. Unfortunately, the cartel's response was to increase prices, using market power to achieve short term profit maximization. Another problem, discussed in Sections 1.3 and 1.4 below, is product quality (including lifetime guarantees). Cartelization and protection are widespread in Brazilian industry and appear to act as a factor inhibiting more rapid market penetration of new technology, though it was not possible to analyse these and other broader economic issues (e.g., inflation) in preparing this paper.

Certainly, progress in creating an overall business environment with more competition, less inflation, and reformed regulation will create more favourable conditions for investment in process productivity and product quality throughout the economy. Yet the existing macro distortions should not paralyse efforts to seek energy efficiency gains (with usually attendant new technology). Indeed the measures described below, ranging from realistic electricity tariffs to norms and information, are compatible with broader efforts to reduce distortions.

1.3 Analyses of specific lighting technologies

1.3.1 Efficient first generation incandescent lamps

Multinational companies operating in the country have already manufactured this product and placed it in the market (22, 36, 54, and 135 W), backed by the hard work of the advertising companies and some support from some government institutions. This was motivated by the government's price control policy and the attempt of the manufacturers to create new products whose prices were not controlled. However, the product was removed from the market with the argument that the consumer was becoming confused with the already existing well-known traditional lamps (25, 40, 60, 100, and 150 W) and preferred these models. This was due to the notion that the consumers were buying a less intensive lamp for a higher or similar price (at the end of the commercialization, its price was equal to that of the conventional lamp), when they chose the efficient lamp.

Various conversations between PROCEL/GERE and the manufacturers—the Brazilian Illumination Association (ABILUX)—show that they were not interested in only producing the efficient lamps because this would:

(i) demand an investment of US $70 million in order to serve the whole market;
(ii) represent a potential risk of a market invasion of imported conventional incandescent lamps since the consumer is used to the traditional lamp;

(iii) demand a great advertising effort in order to educate the consumer, which could be co-financed by the government itself;
(iv) lead to the expectation that the incandescent lamp will eventually disappear from the market, surpassed by the technology of the simple fluorescent lamp, known in the market as the compact fluorescent lamp.

The surcharge which has to be included in efficient lamps, due to the additional investment of US $70 million, is perfectly acceptable considering the benefit offered to the consumer. The Brazilian production surpasses 300 million units/year, which means that an increase of US $0.1/unit will provide a payback time of a little over two years. For an average price of a conventional incandescent lamp of US $0.6 and of electricity at US $0.08/kWh (consumption over 200 kWh/month), we see that the saving of 1.3 kWh compensates for the price increase for the consumer. For a 60 W lamp, this represents nearly 200 hours of consumption (or let us say 400 hours, supposing that the retail price is US $0.2/unit, the consequence of US $0.1 of the retail margin).

The non-existence of such products in Brazil at present can be easily diagnosed as resulting from poor information and poor popular education as far as market demand is concerned, since most of the population is unable to understand the technical and economical advantages associated with the first generation of incandescent light bulbs. Shortage of capital can also create a barrier. The investments required to convert all the existing incandescent light factories can be recovered in a reasonable time span, as discussed above, but there are other investment opportunities in the country which can provide payback time, no shorter than two years.

1.3.2 Second generation incandescent lamps

The much awaited product, 'lamp in a lamp', is already in the American and European market. One can find halogen lamps fitted inside a conventional lamp. This product is interesting because the halogen lamp can reach an efficiency of 20 to 22 lumen/W, almost double that of the conventional incandescent lamp. Apart from this, the halogen lamp lasts 2000 hours instead of the standard 1000 hours of the conventional one.

Another advantage is that, given the small volume of its filament compared to that of the conventional lamps, it is possible to construct a good reflection system with reduced dimensions, projecting almost all the light to a determined area. In this way, a product which is available in the American market, a 'floodlight' lamp, with the reflector system incorporated in the extreme part of the bulb, is capable of supplying light equivalent to a 150 W lamp, with a consumption of only 90 W. This product is economically efficient because its consumer price is US $4 while a conventional floodlight costs US $2.50. This difference in cost (US $1.50), to save 60 W, is compensated with 310 hours of operation (at US $0.08/kWh).

This type of 'lamp in a lamp' does not exist in the Brazilian market. Halogen lamps are produced in the country. Hence it will not be very difficult for the new product brought out by the multinationals operating in Brazil who will have access to the technology. The problem is essentially related to the

capacity of the domestic market to absorb this product. It is estimated that, at present, demand for halogen lamps of general use (including the ones used in the car industry) in the Brazilian market is 1.2 million units/year, 30% of which are imported.

Floodlight lamps are sold in very small quantities in the country. The estimated annual market is 2.5 million units and its cost is four times the cost of the 100 W conventional incandescent lamps. Thus it is difficult to motivate the production of 'lamps within lamps' in the country when the market does not expand. A natural procedure would be to make importation easier and make the product familiar among consumers and project engineers. Importation can be made easier through the reduction or even elimination of taxes, which has already happened with some fluorescent simple lamps.

1.3.3 Third generation incandescent lamps (IRF)—the most efficient one

This product is interesting because the halogen lamp, due to a thin layer of material which is deposited in its interior, provides interference for the light and the heat irradiated by the filament, and can reach efficiencies of 28.6 lumen/W (in lamps of 350 W) and of 35.6 lumen/W (in lamps of 900 W). These numbers are more than 70% higher when compared to the conventional incandescent ones (500 W).

These products are very new in the market and information about them is totally unavailable. Even at the manufacturers' development departments, the information is poorly appreciated. A strong change in the managerial attitude of such enterprises must occur. Since they are all multinationals, it is necessary that they assume the responsibility to use the best technologies.

1.3.4 Conventional fluorescent lamps

These lamps (15, 20, 30, 40, 65, and 110 W) are being manufactured in the country for many decades. The average consumer price (US $5.36, 3.31, 5.36, 3.31, 10.62, and 8.68 respectively) is high when compared to the American market. Total production reaches 30 million units per year.

These lamps, when operated with conventional reactors, register a deficiency in relation to the product found in the US (40 W fluorescent lamps can be acquired in USA retail stores for US $1.50). It is difficult to obtain the nominal value of the flux. Fluorescent lamps of 40 W with a nominal value of 2700 lumen, usually supply 2500 lumen when operated with reference reactors (reactors with strictly defined electrical characteristics) and with a nominal current of 430 mA. In these conditions, it is generally possible to deliver power of 39 W on the lamp's arc, which does not occur when operated with conventional reactors (35 W). This problem shows that there is a loss of 10 to 15% of the normal luminous flux, with a reduction of 10% in the power applied to the lamp. Considering that there is also spent power in the filaments (= 3 W) and loss in the reactor, it may be concluded that the loss of up to 15% of the flux occurs with a power reduction of 10% or less in the combination of lamp and reactor, which means a real loss for the final consumer who is essentially interested in the illumination service at the lowest cost. This loss can be even larger if one considers illumination for spaces with areas over 20 m^2. In these spaces, the smallest light flux may require the installation of one or

more lamps in the illuminating system. This cost of the extra lamp(s) and its installation is a loss to the final consumer. Another problem is that of the average life of the lamp which is not guaranteed by the manufacturer. Data show that fluorescent lamps have an average life of 4000 hours, which is low when compared to that of the American one (8000 hours).

These deficiencies have led to a lot of discussion with the manufacturers who now question the bad quality of various reactors used in the country. The issues detected and discussed above show that a whole new business 'culture' must be pursued. Such a 'culture' should give priority to:

(i) quality control;
(ii) preparation and follow-up of production quality norms; and
(iii) respect for consumer's rights

The last one is obviously linked with adequate information dissemination and with the awareness level of the population. Requiring efficiency standards equivalent to what is achieved in the developed countries will have the indirect benefit of increasing job opportunities for qualified manpower.

1.3.5 Economical tubular fluorescent lamps

In this category, there are T12 lamps (with a diameter of 38 mm) of 37 W and T8 lamps (with a diameter of 25 mm) of 32 W and 16 W, with a luminous flux of 2500, 2750, and 2900 lumens for the first (T8) and 1020, 1150, and 1250 lumens for the second respectively. This variation is due to the use of deposition technology of conventional phosphorous and phosphorous of three different spectrums (triphosphorous). The 16 and 32 W lamps show a gain of 20% in the luminous efficiency in relation to the conventional fluorescent lamps of 20 and 40 W, when used without white luminaries. The gain is even more with reflective lamps, given their smaller physical dimension, when compared to the conventional fluorescent of nominal power of 20 and 40 W respectively.

The lamps with triphosphorous, besides presenting a greater initial luminous flux in relation to the conventional phosphorous ones, also have the advantage of showing a lesser decrease of the flux with time. This is the important for a more efficient project, very often allowing the use of less lamps for the same illumination service, when compared to the conventional phosphorous ones.

The main problems requiring improvements are the ones related to the initial flux which almost never reaches the nominal value and the cost problem. The 32 W lamps with common phosphorous are priced 20% higher than the 40 W lamp, without any justification, except for the novelty of the product. The triphosphorous lamps cost at least 100% more than conventional phosphorous ones, thus discouraging the potential consumers; in the American market the price differential is only 50%. The small size of the market for such products is the consequence of a shortage of information, the high cost of money, and low technical qualifications. Due to high costs, manufacturers need to recover the initial investments quickly. Hence new products are always priced very high, which limits demand. Shortage of demand on the other hand pushes the prices up. Low technical qualifications complicate the development of new products and increases the cost of standard technologies. There are complaints from entrepreneurs not only about such product costs but about other costs that including those

for industrial buildings and associated infrastructure in Brazil, which is higher than in developed countries.

1.3.6 Mercury lamps for public illumination

These lamps are very commonly used for public illumination in main Brazilian cities. The country still uses a reasonable quantity of incandescent lamps (= 600 000 units) for this purpose and its most natural substitute is the mercury vapour lamp. The commonly used models vary between 125 and 4000 W and are preferred for their lower price.

Mercury vapour lamps are sold with the life expectancy of 12 000 to 15 000 hours, and the available data show a life duration of about 8000 hours. It is difficult to determine whether the deficiency comes from the lamp, as, very frequently, the discharge current (in the ballast) and control of luminous flux (with the luminary) show a performance in service which is seldom evaluated and sometimes does not meet even Brazilian norms.

With regards to its luminous flux, the result obtained for the Brazilian product is equal to the lamps produced abroad. Unfortunately the local manufacturer does not guarantee the average life of the product. Only one of them states the nominal life average obtained in a laboratory in his catalogue.

1.3.7 High pressure sodium vapour lamps

These lamps (with internal igniter—'starterless' lamp) have been used increasingly in public illumination in Brazil. Inspite of being more efficient than the mercury ones, its market is limited by the production cost. Part of its components are imported which implies an increase in the final cost due to import tariffs. With the liberalization of imported goods in the country, these tariffs were reduced and more reductions are expected in 1993 and 1994.

The life expectancy of these lamps can go up to 24 000 hours though the manufacturer does not guarantee this. In practice, shorter lives have been observed (6000 hours) and it has been blamed on the inappropriate performance of the auxiliary start-up and operating system. In relation to the price, it is also important to verify that, for the same amount of luminous flux, they cost between 2.5 and 4 times more than the mercury lamps, which is high when compared to the price in the US (where it costs between 2 and 3.5 times more than the mercury lamp).

The performance of mercury and sodium lamps is another evidence of the poor technological level. There is a shortage of qualified people to deal with the problem on the producers' and consumers' side. Consumers' rights are neither respected nor claimed, and this leads to a loss for the whole society.

1.3.8 Compact fluorescent lamps

Compact fluorescent lamps (CFLs) have been offered in the Brazilian market for five years, with a power of 5, 7, 11, and 13 W. Like all other discharge lamps, they need current limitation reactors. They are found in the market, either incorporated with the reactor or not, and have sockets which are

compatible with the conventional incandescent lamps. The units with the incorporated reactor are imported, without any import tax, while the bulbs up to 13 W are manufactured in the country by multinationals. The market of these products in 1991 was of 0.8 million units of which 63% were produced in the country, 33% were assembled in the country with the majority of foreign components, and 4% were imported. Their retail price is US $6 without and US $11 with the reactor. There are also CFLs with electronic reactors in the domestic market, which can be imported and sold in retail for US $15. CFLs are manufactured with triphosphorous and therefore are more efficient. Inspite of this, they do not compete with the efficiency of the conventional fluorescent lamps of 40 W because they are designed for low power only.

In spite of their high unitary cost compared to that of incandescent lamps, CFLs have the advantage of being replaced easily (as in the case of incandescent lamps), are four times more economical, and demand less maintenance due to their average life span of 8000 hours. Even though this fact is not guaranteed by the manufacturer, many users are satisfied with the reduction in the cost of replacement.

If we consider a power of 12 W for the combination of lamp–reactor (9 W), for a period of 8000 hours (the normal life declared for this type of lamp) and compare this system with the traditional incandescent lamp of 60 W nominal, with respect to costs of illumination per million lumen/hour, the cost of the first is US $5.09/million lumen/hour (fluorescent 9 W) against US $9.60/million lumen/hour for the latter (incandescent). If we divide the mentioned period (8000 hours) into eight regular intervals to be paid by the consumer, we will have a lower cost for the same benefit, after 2.5 intervals, and illumination for the consumer who can choose the fluorescent system.

Without any doubt, at first sight, this tacky economical argument is able to change CFL technology into a very attractive alternative for the replacement of conventional incandescent lamps. However, if we examine some other points, we will surely revise this position. To mention a few (as their discussion is not our main objective):

(i) necessary time (about 45 minutes) to attain the standard luminous flux;
(ii) maximum luminous flux is a function of the angle of installation and operating temperature;
(iii) strong dependency of useful life on the number of times it was switched on;
(iv) control over the rejected mercury after the lamp's use. At 5 mg mercury/lamp for 200 million lamps/year, we will have approximately 187 tonnes of mercury per year, if these lamps survive 8000 hours, that is eight times more than the conventional incandescent lamps.

In this way we clearly see the necessity of revising the cost of illumination in relation to the usage habit, beyond the concern for clear definitions on the recycling of mercury. At present, we think it would be convenient to recommend the use of this type of lamp for areas with continuous and uninterrupted power supply periods, i.e., above six hours/day (as it occurs in the commercial sector).

The CFL lamps with inlaid electronic reactors can be manufactured in Brazil. According to the multinationals, the existing barrier is only due to the low demand of the product in relation to its high cost. Inspite of this difficulty, it is natural that electronic reactors are used with CFL lamps because

of their low losses. Electromagnetic reactors can show a loss of 4 W, which is very significant while operating lamps with a consumption of 7 W.

Besides this, compatibility in the physical size is essential, so that the replacement of the incandescent lamp for the CFL may be easier. CFL lamps with inlaid traditional reactors last much longer, while the use of the electronic reactor allows a reduction in the physical dimension.

The use of CFL lamps encapsulated in glass is also becoming very popular because they are able to simulate the colours of the incandescent lamps better. This product is preferred as the colouring of the incandescent lamp today is better associated with residential environments, with the exception of the service areas in the house. This product already exists in the Brazilian market, imported by the multinationals and sold at a price of US $20.

1.3.9 Dichroic lamps

These are halogen lamps incorporated to a reflection system which has the characteristics of reflecting only visible radiation (light) in a given direction and transmitting heat in the opposite direction. Therefore, this type of source already has, in an improved way, its 'own luminary', and emits a cold light, which, when compared to the conventional incandescent lamp, gives excellent colour reproduction. For certain applications it is much more efficient, with respect to energy, than conventional options.

These lamps are available in 20, 50, and 75 W, with a two-pin base for a 12 V nominal tension (which demands a transformer or electronic converter—both in use) at price of US $15 per unit. There exists in the market a lamp for voltages similar to Brazil's grid (code ELH, 300 W, 120 V), but they are imported and their use is restricted due to their high power.

They have very limited use for decorative purposes, being used almost exclusively by the upper social classes who can afford it. The reduction of light intensity is common ('dimmer') for the reduction of its work tension. Halogen lamps have a nominal life span of 2500 hours when operated at nominal tension, for this is the condition for the regenerative cycle to occur. The cycle does not work with tensions below the nominal and in this way durability becomes that of a conventional lamp (about 1000 hours).

1.3.10 Conventional light fixtures

The use of light fixtures as part of the illumination system with fluorescent lamps is very common in the country, even though there are simpler areas where mere bulbs are used. The conventional light fixtures have more decorative value and do not improve the illumination efficiency. They are generally made with iron sheets enamelled with white paint. The white paint guarantees a good reflection for the light that the lamp emits, which is directed upwards. The reflection index of the white enamelled surfaces is approximately 90%, which apparently shows great efficiency.

Due to architectonic reasons, and less frequently, due to technical reasons, it is common to use an opaque or semi-opaque material near the base or flaps, also made in white enamel. The opaque material can absorb up to 50% of transmitted light, while semi-opaque materials of better performance

absorb 20%. The flaps also reduce efficiency, absorbing and reflecting light in directions which do not fall within the working area. Inspite of the opacity being a problem in working areas, the use of flaps and translucid materials is common in light fixtures placed in circulation areas.

1.3.11 High efficiency light fixtures

It is possible to prove that light fixtures which are made with the appropriate geometry and with reflective material can supply illumination up to two times higher than that obtained from conventional ones. The reason for this improvement lies in the fact that the reflection index which is only of real interest in a material in order to justify its luminous efficiency, is the intensity of the specular reflection and not the intensity of the diffused reflections. Enamelled and white painted surfaces have a high index of diffuse efficiency, which is the measured light intensity reflected in the whole hemisphere. A high coefficient of specular reflection means that almost all the reflected light is in one determined direction, in accordance with the law of optical reflection.

When good reflective material is available, specular reflection takes place, allowing the elaboration of a good geometry with the objective of diffusing this light to the area of interest. In the case of diffuse reflection, the light which falls on a determined angle is spread in all directions, including the ceiling and the wall, where there is no need for illumination.

Optimized geometrical forms may be calculated and some manufacturers already produce these light fixtures in Brazil obtaining an efficiency of nearly 90%, inside a spheric cone with an opening of 60 degrees (the measurement between the generating line of the cone and its median line) centered in the fixture and with its base on the ground. Even though the manufacturers do not totally understand the optimized geometrical form, practical experience and the availability of good quality reflective materials, already allows this type of product to be found in the market. The reflective material which has been mostly used is the Silverlux film, which is imported from the US and offered in the domestic market for US $30/square metre. It is a film composed of a silver deposit on top of plastic on one of the sides, while the other side is made of a self-adhesive material. Another product which is available in the American market is the metal sheet on which the manufacturer has already fixed the film. Silver deposition demands sputtering techniques and its price in the Brazilian market may reach approximately US $20/m^2 already considering the metallic material. The first option has been used mainly for application on aluminium. Other types of material have not offered satisfactory adherence. The second option may be applied on aluminum and iron sheets, which is another economical advantage.

Besides these two alternatives, anodized aluminum sheets and glass mirrors are also used as reflecting material. Highly reflective anodized aluminum is not available in the country and the anodization has to be done, in small enterprises, on demand. The procedure has almost no quality control, which means that according to the lot, the quality of the product varies. Anodized aluminum reflectors were never produced in this country with the same quality as those found in the industrialized countries. Even though the mirrored glasses are of an excellent quality, they have the inconvenience of weight and high application cost on metals, requiring glue and adhesive tapes as well as a great quan-

tity of labour. The possibility of importing anodized aluminum of great reflective power was considered by ABILUX but never took place.

Some tariff barriers on the institutional side were removed in order to make importation easier. GERE, an inter-ministerial entity, was able to obtain a reduction from 25% to zero of the import tariff on Silverlux films, which allowed its sale for US $30/m^2. Other efforts made in the same direction for anodized aluminum and sheets with applied films have not shown any results as yet. The impact of the importation tax on the product's final price is relatively higher than the reduction in percentage of the tax, because other federal and state taxes are also charged along with the service taxes of ports and airports. An estimate shows that with a custom tax of 25%, a product which is imported in lots at a value higher than US $10, ends up with a cost 80% higher than the import price, after all the taxes and services are paid. A reduction to zero of this tax shows a decrease to 45% on the final import price.

In the case of the efficient light fixtures, we observe that information about these is known to a small elite since 1990, when a small pioneering competition promoted by the University of São Paulo requested for light fixtures with an efficiency superior to 42 lumen/W from the market. This information has been spread since then and there are already some enterprising groups who have demanded the use of efficient light fixtures in their projects for 1992. The main manufacturers are also aware of the product's existence and of its potential in medium term. Some engineering companies are still misinformed and this has caused technological inertia.

Regarding production capacity, a profound knowledge of the required geometry already exists in the University as well as knowledge acquired by some manufacturers by the trial and error method. The marketing personnel are still not prepared to sell the product for they have not understood the advantages of the equipment and therefore find it difficult to sell. More advertising of the product is essential, as well as holding of conferences and seminars, capable of attracting project engineering companies.

There are still some difficulties in the case of technology for the preparation of the material. The technique of metal vacuum deposition by evaporation is practised commercially for the deposition of aluminum in plastics. The ion-sputtering technique is well understood and used in universities and research centres. One of the big light fixtures firms is a multinational enterprise, which has no difficulty in bringing in technology from its headquarters. If the other enterprises would be motivated by their competitors, they could bring the deposition equipment from abroad and find local expertise and labour to produce them. The lack of interest in the production of the reflective material is primarily due to the small market. Until now, reflective light fixtures were sold in quantities of several thousands per year and have not become a big business yet.

Another problem which hinders the use of the product, caused due to the lack of technical competence of the buyers, is that they buy the efficient light fixtures because of their appearance and never worry about quality tests, either when choosing or receiving the merchandise. This works against technological progress because, on one hand, it allows bad quality products to be sold, and, on the other hand, the buyer is not satisfied with the new technology, thus delaying its use.

1.3.12 Electric reactors for gas discharge lamps

In the last decade, the first noticeable step towards the improvement of the energy performance of the conventional fluorescent system (40 W) was the introduction of the switch (bimetallic) placed in series with the filaments and in the interior of the discharge tube of this lamp. This resulted in a lamp of nominal power (37 W) which means that the loss in the filaments (3 W), during the functioning of the system, ceases with the interruption of this circuit after the ignition of the lamp. Unfortunately the knowledge of this technology has had very little effect and only one manufacturer in Brazil produces this type of lamp.

Approximately three years ago, this same idea (of disconnecting the filaments) which is able to reduce more or less seven per cent of the power of this type of lamp (40 W), was launched in the Brazilian market by manufacturers of conventional reactors. This innovation consists of an electronic switch which disconnect the coils that feed the lamp's filaments automatically after the start. This innovation does not yet have the potential of being rapidly accepted in the market as it requires new installation and eventual substitutions (the conventional reactors have a life expectancy of 10 years) and awareness has not spread as expected. We believe that the price difference in relation to the conventional reactor and the lack of consideration for small economies, on the part of the project engineers, are responsible for the reduced usage of this product.

The first technical developments with views to obtaining the electronic reactor were also started in Brazil at the same time three years ago. There are, today, at least five manufacturers who have this product for commercialization and we know of others who are still developing it. Some of the prototypes we examined show that:

(i) the electric current in the lamps discharge has a frequency above the audio band;
(ii) the relative efficiency of the system (in lumen/W) is located in the band of +20 to 30%, when referring to the conventional reactors (electromagnetic) for two fluorescent lamps;
(iii) the power absorbed from the network for the same luminous flux is –20% in relation to the conventional reactor; and
(iv) the electric efficiency is superior (90%) against the (75%) of the conventional reactor;

However, inspite of the above mentioned advantages, in some prototypes, the power factor is still around 60%.

1.4 Barriers and possible lines of action

The technology defined cases described above point towards several major problems/barriers for the market penetration of energy efficient lighting equipment and design. Observations made at three professionally oriented seminars during the Rio summit in 1992 complement and broadly support this early diagnosis.

The problem of quality control in the manufacturing of lighting equipment appears to be widespread. This can be seen with the lamps' lifetime. Guaranteed lifetimes often do not even exist. The

past record for many key and already commercial technologies is frequently poor. High pressure sodium lamps appear to have a real world lifetime in Brazil of 6000 hours *versus* a norm of 25 000 hours. Uncertainties regarding this basic parameter can play havoc with any financial/entrepreneurial analysis of additional investment in lighting efficiency. This is not entirely a problem of manufacturers' quality control. Maintenance, operations, and uncertainties regarding the specified quality parameters of electricity supply—all play a role. Equipment lifetime is not the only aspect of the quality control problem.

The problems of operations and maintenance, not to mention appropriate initial design of lighting systems, make training programmes for technology users a high priority. This 'human resource' theme will be returned to, because it is central to energy efficiency initiatives in consumption sectors with very different characteristics. The priority need for 'education/training' and accessible information permeates most of the Brazilian analysis of how to 'modernize' the economy. This is partly a consequence of the low standards of education, especially basic education, as already discussed.

The problem of overall quality control affects both 'conventional' and more advanced/efficient lighting equipment. Advanced equipment suffers from a greater relative price differential which is more than that of the industrialized countries. This greater differential inhibits a shift towards more energy efficient equipments. Several factors can play a role in creating it. First, the industry is cartelized and has considerable protection for its products. Second, imported components weigh more in energy efficient equipment and tariffs, are levied on these though the reduction of import barriers has been achieved for certain key components. Finally, the small size of the market keeps costs high. Strategies are needed to break the high cost–high price–small market triangle which particularly limits some technologies. Larger market volume can help reduce costs, opening new segments of demand in a vicious circle.

Several market oriented approaches are worth following. Financing mechanisms to reduce initial costs appear to be necessary. Capital is very expensive in Brazil. It can earn 20% (real) in highly liquid low risk papers. The expected discount rates for personal consumption decisions are often much higher. In addition, many lighting systems are purchased and installed by entities who will not pay the operating bill and who think only of minimizing up-front costs. Different mechanisms and institutions will probably be required for different segments of the lighting market. At present, no line of credit exists for any end-user investment in efficiency.

Another complementary approach emphasizes increasing the awareness and information available to potential investors while reducing their 'transaction' costs in planning and carrying out energy efficiency investments. A good example of this approach is the 'Green Lights' programme created in early 1991 in the US by the Environmental Protection Agency. A variant of this programme is being established in Mexico and another is under consideration in Brazil. In the US programme, a firm makes a voluntary signed commitment to retrofit 90% of its building area with cost-effective efficiency improvement (return = six per cent above the prime rate). In return, it receives free training, software, and information on equipment, financing, etc., which helps to reduce the 'transaction'

costs of an enterprise—a wide programme on a subject generally treated with least priority. It also receives favourable environmental publicity, while the same publicity serves to make the public more aware of the commercial potential of lighting efficiency improvements. The kinds of market imperfections addressed by 'Green Lights' are fairly universal, hence the interest in adapting this rather successful programme to Brazil. Negotiations have only begun, but it is likely that the programme will take a rather different shape in Brazil even if much of the software and kinds of information are transferred. For example, access to financing (not just information) is likely to be much more important. This could, in turn, influence how the audits of cost-effective investments are carried out. The transfer of 'Green Lights' from the US to Brazil should provide interesting insights on how market imperfections and their impacts differ in an industrialized and in a developing country situation. It is also an example of an important kind of technology transfer which involves virtually no hardware.

Another market-oriented approach would be to reduce restrictions on the imports of certain components or final products. This need not be a blanket easing—energy efficiency criteria can and should be used. This kind of measure should facilitate the entry of new, more efficient products. This would create an initial market demand which can then 'pull' in investments in domestic production. The difficulty in creating an initial market demand has been a barrier for some technologies discussed above.

Market (or business facilitation) oriented measures must be complemented by 'command and control' measures of the government. The most obvious of these are standards for minimum energy performance. Although these have not yet been applied to electricity end-use in Brazil, they are regarded as important for some sectors (e.g., refrigeration and air conditioning). The application of strict energy standards for basic lighting products may be less important or viable. However, the whole issue of quality control raised earlier makes norms very relevant in general. Another set of issues that have a bearing on norms and standards involves labelling. Most lamps are judged by their power input and not their luminous output. This led to a surrealistic impasse on labelling norms that contributed to the demise of the 'energy saver' (first generation) incandescent bulbs described earlier. Implicit in labelling programmes or the establishment of norms is the existence of neutral laboratory facilities for monitoring performance of different products.

Another set of 'command and control' measures involves government regulation in the electric utility sector. The need for regulatory reform, part of a wider change in the institutional/ financial model, is recognized as urgent, though negotiations have been complex and slow. Reform is likely to be necessary if utilities in Brazil are to make significant investments in end-use efficiency and firmly incorporate 'demand-side management' (DSM) into their service expansion strategies. Distribution utilities especially need little financial incentive to promote DSM. International experience suggests that active utility led DSM programmes can make an important contribution to overcoming market imperfections. In the US, they were crucial to the consolidation of 'Energy Service Companies' (ESCOs) though ESCOs do not necessarily imply DSM. These new intermediaries help reduce the transaction costs and risks of energy efficiency investments.

ESCO-type companies exist in Brazil, but their market is still very precarious. The consolidation of this kind of service could contribute to easing market acceptance of lighting and other efficiency improvements in the commercial and industrial sectors. Utility-led DSM is still very limited in Brazil. Though regulatory reform is ultimately necessary, it would be a mistake to paralyse DSM while waiting for this unpredictable process to reach a conclusion. There is a great need for pilot programmes to develop and test various measures.

So far, electricity pricing has not been discussed. The average electricity tariff in Brazil is substantially below the marginal cost of supply. There is an important school of thought coming out of neo-liberal economics which believes that if the price were brought up to the marginal cost, optimization of demand would occur almost automatically with a helping hand from trade liberalization. Most measures raised above are of little or no value in this view. The authors do not agree with this diagnosis. Full cost pricing is neither a necessary nor a sufficient condition for achieving cost-effective energy efficiency gains. Obviously, it is desirable that prices reflect full marginal costs (including externalities) and higher prices will clearly help make additional energy efficiency gains viable. However, even with the existing inadequate tariffs, many efficiency investments are cost-effective (Poole, Moreira 1992). Furthermore, in at least two sectors of demand (low voltage commercial and larger residential), existing tariff levels equal or exceed the marginal cost. These two sectors also offer a rather effective rebuttal of the purist neo-liberal view that full cost pricing is sufficient to stimulate an optimized demand adjustment. By this view, the efficiency of energy consumption in these two sectors should be markedly better than in the rest. There is no evidence that it is. Either consumers are correct to let opportunities to earn returns of 30 or 40%, or more, to pass by, or there are serious market imperfections at work. We believe that the latter alternative is more reasonable and far more abundantly documented. The measures discussed above are attempts to address these market imperfections. This does not advocate a philosophy of government intervention. The measures proposed have the objective of helping the market adjust closer to the new optimum suggested by the electricity price signals. The kinds of measures being discussed should be regarded as a key complement to pricing policy, partly in order to help it work better, and partly in order to make the necessary increases in average tariffs politically acceptable. This latter point is very important and has not been adequately considered. If prices were easy to increase to a desired level by government decree, this would have been done long ago. The World Bank has been pressuring Brazil's electrical sector on this point since 1984, and power sector loan negotiations have been discontinued as a result.

Any discussion of pricing and of utilities' supply/demand strategies in Brazil cannot ignore the importance of inflation, the uncertainty regarding when and how a sustained economic recovery will occur after twelve years of stagnation, and the near certainty that any recovery will quickly hit the limits of electricity supply. Brazil is a country with a long history of high inflation. This history generates a culture. For example, businessmen can quickly reckon (correctly) that, at moments of increasing inflation, the government can be relied on to hold back on electricity tariff increases, as is occurring again now. This short-term signal influences priorities. By and large, the effects of a 'high

inflation culture' are inimical to energy efficiency improvements, or indeed to any major productivity, enhancing investments in industry and commerce. Firms dedicate disproportionate senior management to short term financial intermediation. Consumers find it difficult to do more careful 'comparison shopping'. Successive macro economic shocks to bring down inflation add to the uncertainty which complicates and inhibits investment decisions.

The hibernation of Brazil's fundamentally dynamic economy since 1980 has permitted the country's state-owned hydro-electrical sector to usually satisfy demand without any rationing except for two brief occasions—1978 and 1986 in the southern region of Brazil, and in 1979 and 1987–88 in the area reached by the north–north-eastern grid. This relatively good performance of a state-owned infrastructure sector in an extremely adverse business climate has probably lulled Brazil's key political and business decision makers into a false sense of security regarding an extrapolation of business-as-usual behaviour. However, among strategic thinkers in the electrical sector the consensus is different. Unless measures are taken soon to enable Brazil to exploit its large potential for electricity conservation and private sector investment in generation, it would be physically and financially almost impossible to meet the electricity service requirements of a sustained and rapid economic recovery. Again, San Pedro's rains are an element of uncertainty. This consensus in definition of the problem has lead to the creation of a non-governmental organization (NGO) in Brazil for addressing it. The existing institutional channels for catalysing such wide ranging changes were felt to be inadequate. This new kind of entity is appearing under various guises in Eastern Europe, the ex-Soviet Union, and other Latin American countries, though there are important differences in priorities and styles. Will they be able to contribute significantly to improving energy efficiency? In Brazil, at least there is a belief that such an entity can make a difference, catalysing and leveraging larger investment flows and helping to create markets for relevant services. Given the challenge of rapidly introducing energy efficient technology in developing countries, the role of such NGOs and the possible off-shoots should be tested, stimulated, and monitored.

1.5 Conclusions

There is a very large theoretical cost-effective potential for energy efficiency savings in lighting. The rate of penetration of improved technology will depend on policy towards electricity tariffs and whether market barriers which inhibit economically efficient consumer adaptations are effectively addressed. The realization of the former may depend on progress in the latter. Achieving the latter will require creativity and changes. These range from independent and transparent regulatory organs of the government to private companies, specializing in new market services (including subsidiaries of utilities), to NGOs.

Within the context of encouraging policy making towards energy efficiency overall, lighting is an interesting primary priority. The end-use equipment is relatively short-lived. This means that changes in the profile of new equipment sales can influence the energy profile of the operating stock of lighting equipment more quickly than is possible in most energy consuming sectors. Moreover, while there are millions of consumers of lighting equipment, the manufacturers of basic equipment are

few. It is therefore, possible to define market segments. This simplifies policy making. Furthermore, light is highly 'visible'. These characteristics together make energy efficiency in lighting an excellent target for a multifaceted programme which can show palpable results in a relatively short term. The programme will also have an impact on public awareness of the potential for energy conservation, and show how to do it. This is a basic premise of the 'Green Lights' programme in the US, discussed earlier, which may be interesting to explore in developing countries.

The relatively slow penetration of more energy efficient technology and systems in the lighting market is a result of factors on the supply and the demand side. On the supply side, this report has raised pervasive problems of quality control and larger price differentials between conventional and more efficient lighting equipment. An approach to both problems involves liberalizing imports of final products and components. Technology development and acquisition do not appear to be bottlenecks in the lighting sector, though the costs of technology acquisition were not fully analysed in detail for this paper.

While supply-side problems exist, the most important drag on penetration has been the lack of demand 'pull' for new products. The lack of demand volume helps maintain high equipment prices. Various studies have shown that very high returns can be gained on many investments in lighting efficiency, even with existing unsustainably low tariff levels. This paper has presented some of the major barriers to realizing this potential: financing, information/awareness, transaction costs, and the lack of skilled service intermediaries. Some initial lines of action have been sketched out. Brazil is well down the learning curve for these kinds of measures. For example, the only public sector credit-line for energy efficiency was recently cancelled due to lack of application. It is an urgent priority to start launching a series of pilot programmes.

It will be very difficult to fully finance these pilot programmes domestically, even though their requirements are small, relative to supply investments. The government cannot escape deficit, inflation remains very high, and the utilities face a financial crisis. There is a very strong case for catalytic international financing, especially from the multilateral development banks, the International Finance Corporation and the Global Environment Facility (GEF). There have, however, been strong impediments to such financing. In the case of the World Bank, the priority is to pressurize for closer approximations to the full marginal cost of electricity supply. Adequate operational mechanisms to finance end-use efficiency projects are not yet in place. There may be changes as a result of an internal review of the Bank's role in promoting energy efficiency which is currently underway. The Bank has, in any case, not made any new power sector loans to Brazil for quite some time, since the government's commitment to increase average tariff levels has not been fulfilled. One way out of this impasse might be to finance a package of structural adjustment measures—such as energy efficiency, utility DSM programmes, and private sector power generation and cogeneration—which can create an improved climate for achieving and maintaining adequate electricity tariffs, among other things.

In the case of GEF, the criteria for project approval have so far been highly unfavourable for the most interesting energy efficiency programmes. These generally have relatively high economic returns, whereas the GEF is supposed to finance low return projects in order to bring returns to an

acceptable level. As a result, the GEF has had to play down the most promising area for CO_2 abatement in energy. Interpretation of these criteria has gone back and forth during the GEF's pilot phase. It is to be noticed that with the GEF's consolidation of the Rio Summit—1992, a compromise can be settled to allow financing of innovative energy efficiency programmes. Perhaps greater emphasis should be placed on market barriers rather than on the projected economic return of a successful programme.

Whatever be the source, external financing can accelerate the consolidation of policies to overcome market barriers to energy efficiency improvement and the diffusion of new technology. The returns should be adequate enough to attract increasing levels of local financing.

2 COGENERATION TECHNOLOGIES IN BRAZIL—POTENTIAL AND LIMITATIONS

2.1 Introduction

Cogeneration is defined as the production of electricity and usable heat from a single thermodynamic machine. Opportunities to increase the supply of electricity through the use of central power stations are being reduced due to escalation in investment costs, and the concern with environmental degradation—locally or at global level. This is always associated with more energy production (ISES 1992). Decision makers are becoming more interested in the use of energy with high efficiency. One way to save energy is through the development of cogeneration plants by industries which use significant amounts of thermal energy for process heat or for space heating and cooling. Electric generation through a thermodynamic cycle always produces heat as a by-product. If this heat can be used, we have the potential to save considerable fuel. Obviously central power plants also have the possibility to operate in a cogeneration mode, where the waste heat is sold to residential customers for space heating or to industrial customers for space heating or as process steam. This case requires installation of a steam distributing network in cities, which implies a large investment and is more suitable for temperate countries. In this paper, however, we will not discuss this technology.

Here the discussion is divided according to the final use of the heat produced. Under Section 2.2, we present the possibility of using heat as a source of more electricity. Section 2.3 discusses the option of direct final use of steam and in Section 2.4, the particular case of using heat as an energy input for cooling air. Section 2.6 deals with the possibility of using the new generation of gas turbines for cogeneration units. Sections 2.5, 2.7, 2.8, and 2.9 deal with specific cogeneration applications in Brazil and their consequences. It is not our intention to present all possible cogeneration schemes according to the final use of heat as well. We have only selected the most important cases in the Brazilian context.

2.2 Cogeneration for central power stations

The cost escalations, that have made coal-fired steam electric plants expensive and have essentially killed nuclear power as an option for new construction in the foreseeable future in the US, are partly due to tightening environmental and safety rules.

Figure 1 shows that in the US the electricity price had been declining from 1935 to 1973. The prices shown are the total revenues divided by the total electricity sales (Poole, Moreira 1992). After the oil shock, prices increased. Even after 1982 with a decrease of 70% in oil prices, the average electricity price has declined only by four per cent (Williams, Larson 1988). The main reason for this price increase should not be attributed to the price of fuel, but to the fact that the capital costs of central station power plants have escalated dramatically.

Electricity rate increase and the Public Utility Regulatory Policies Act of 1978 (PURPA) have led to a competitive challenge for utilities from independent cogenerators and small power producers. PURPA requires a utility to purchase electricity from cogenerators and other qualifying independent power producers at a price equal to the utility's avoided cost.

The greatest challenge to utilities from cogeneration comes from the basic industries using steam, where the economics of cogeneration is most favourable. Under this condition, in 1987, the Federal Energy Regulatory Commission (FERC) in the US began considering the establishment of a scheme to allow competitive bidding for utilities incremental to power requirements—a scheme that would allow cogenerators, small power producers, other independent power producers, and utilities to compete on the same basis (FERC 1987).

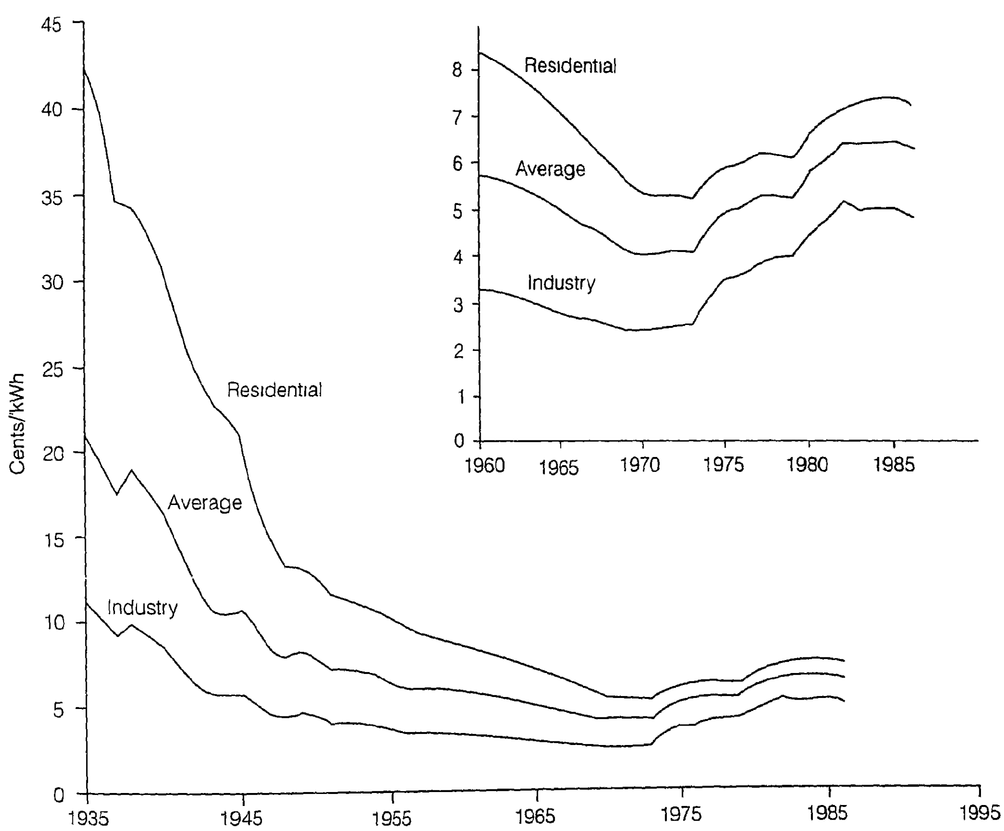


Figure 1. Long term and recent electricity price trends in the US
Source. Williams, Larson (1989)

To compete with cogenerators, utilities have to exploit the possibility of improving the efficiency of traditional steam-based electricity generation or search for alternatives that will allow them to use the produced heat as a source of more electricity. Unfortunately the possibilities for improving efficiency of steam-based plants are not good. The efficiency of modern fossil fuel-fired, steam-electric power, working at steam pressures as high as 24 MPa and temperatures of 540 °C, has not improved since 1950 when such peak steam temperatures were reached. Under such conditions, as shown in Figure 2, the maximum net efficiency of a steam plant does not surpass 40%. This is quite low when compared to the full energy efficiency (80%) reached by cogenerators (Williams, Larson 1989).

One possible alternative is the use of combined cycle technology. Combined cycle technology is familiar to the electric utility industry world-wide. In a combined cycle, a gas turbine produces mechanical energy to rotate an electric generator and produces heat in the form of a hot air exhaust that is used to heat water and produces steam which drives a conventional steam-based electric generator. The interest in this technology has increased in the last 10 years, since gas turbines have become almost as efficient as the best steam turbines. Up to the early 1980s, the attraction of gas turbines for utilities has been its low cost of $300/kW or less (EPRI 1986), a small fraction of the cost of coal or nuclear plants (Williams, Larson 1988). Simplicity has been the major target of gas turbine constructors and even though the turbine inlet temperature is high in a gas turbine (1100 °C compared to 540 °C in a steam turbine), the efficiency has been less than 30%. This constraint associated with the cost of better quality fuel (natural gas, kerosene, or diesel oil) limited the gas turbine in utility applications mainly to peaking service.

More recently, several improvements in the design of gas turbines, mainly smaller sizes of the aero-derivative type, have significantly increased efficiency. For example, a combined cycle was put

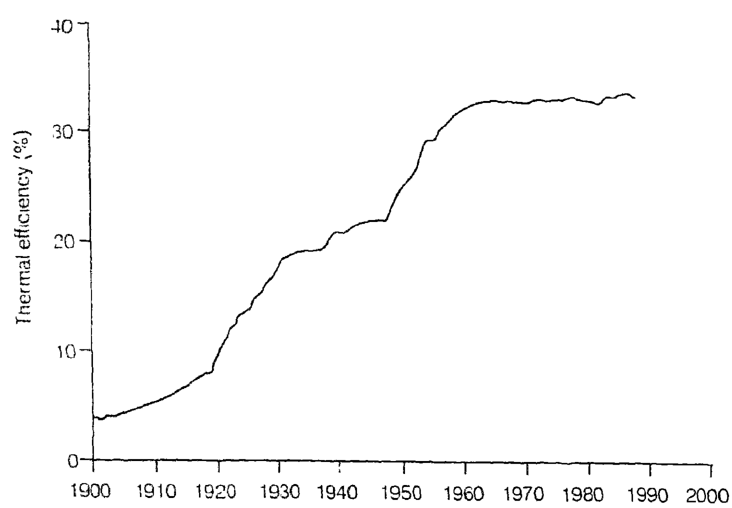


Figure 2. The trend in the average efficiency of electricity generation in centrally stationed thermal power plants in the US
Source. Williams, Larson (1989)

into operation in 1986, for the N V Ijsselcentrale, a Dutch utility company, with a gross power efficiency of 50% (Broekhuizen, van Lavieren, Kamming 1988). The plant uses two (LM 2500) gas turbines, one steam turbine, and the electric generator linked together through only one axis. Power output of both gas turbines is 42 MW with a total efficiency of 35% while the steam turbine provides 18 MWe, allowing a gross power output of 60 MW. Total natural gas consumption is equivalent to 119 MW, yielding a total efficiency of 50%. This system has a remarkable efficiency but due to the use of a small size steam turbine is priced above US $1000/KW, as shown in Figure 3.

Other improvements have achieved high efficiency with a price per kW very much the same as the single cycle gas turbine. The improvements allow the use of the heat released with the exhaust gases to produce steam which is injected back into the combustion chamber of the turbine. These units called STIG are being used in commercial applications and there are 30 units in operation, construction, or under order in the US alone. The largest unit commercially available is based on the GE LM-5000 turbine (used in Boeing 747s). As a simple cycle, it produces 33 MWe at 33% efficiency when operated on natural gas fuel. With full steam injection, this engine produces 51 MWe at 40% efficiency. Turnkey STIG units of this capacity packaged on a skid and without a building are commercially offered for about $700/kWe (Bemis *et al.* 1989).

Another alternative to steam-based power plants is to use the evolving technology of the combined cycle. For example, the GE LM-6000 which should be in the market in 1992, will produce 42.4 MWe at a simple cycle efficiency greater than 36% using natural gas and will have an estimated genset equipment price of $250/kWe (Biasi 1991). Combined cycles based on the LM-6000 are expected to produce 53.3 MWe at an efficiency of 48% (Macchi 1990).

Obviously such remarkable performance is attractive, but the total electricity generation efficiency is not above 50%, which is low compared to the 80% efficiency obtained when steam and electricity can be simultaneously used as end applications (Broekhuizen, van Lavieren, Kamming 1988). Nevertheless, central power stations with such efficiency are able to compete with steam and electricity cogenerators because electricity has a higher value when compared to steam.

2.3 Steam and electricity cogeneration

This is a well-known commercial practice. Almost all producers use a steam Rankine cycle, a technology nearly 100 years old. In general, the higher the peak temperature of the working fluid, the higher the thermodynamic efficiency of a power generating cycle. Most of the units are small in size (up to 30 MWe) as compared with central power stations (200 MW and more). Due to the small size, the economy of scale imposes high investment cost per kW, as shown in Figure 3, and also limits the maximum achievable electricity efficiency. Such units when designed only for power production have efficiencies of 14 to 18% in California (Williams, Larson 1993) and from 10 to 16% in North Brazil as shown in Table 1.

Such levels of power generation efficiency are achieved with a fully condensing turbine. When large amounts of steam are produced, the power generation efficiency can be as low as five per cent,

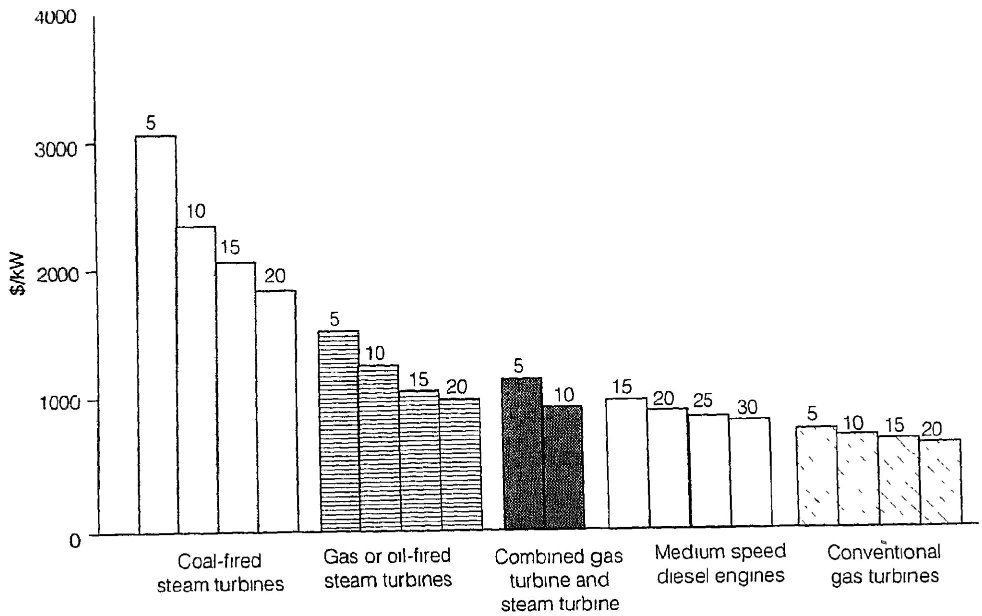


Figure 3. Units installation costs for small scale cogeneration systems. The numbers at the top of the bars are the installed electricity generating capacity in MW (1985)
Source. Williams, Larson (1989)

as is very common in sugar mills in Brazil (Poole, Moreira 1979). Such low efficiency is the main reason why small scale electricity production is not understood as a good business for large entrepreneurs.

2.4 Air cooling and electricity cogeneration

This technology has been well known for several decades but it has become the object of commercial interest only in the last few years. Air cooling can be obtained with absorption pumps that use hot air or steam as the provider of energy input.

Table 1. Efficiency and capacity of cogeneration units in North Brazil (1985)

Cities	Utility	Capacity (MW)	Investment (US $million)	Efficiency (%)
Cruzeiro do Sul	Electroacre	6.0	18.0	13.6
Tarauaca, 'Feijo'	Electroacre	3.0	8.7	14.6
Sena Madureira	Electroacre	1.5	4.5	14.6
Guaina	CERON	6.2	17.5	13.2
Boca do Acre	CEAM	3.0	8.7	16.2
Carauari	CEAM	3.0	8.7	16.2
Eirunepe	CEAM	3.0	8.7	16.2
Ariquemes	CERON	8.0	20.7	9.7

Absorption cycles use a vaporizable liquid, e.g. ammonia, as a refrigerant and a second liquid, e.g., water, as an absorbent for the first. A schematic diagram of the flow process involving both water and ammonia is shown in Figure 4. The right-hand side of the diagram is identical to the condenser–evaporator arrangement of a device utilizing the vapour compression cycle, except that there are no longer a compressor and a throttling valve linking them. Instead, heat energy is used to drive an absorption generator unit which effectively acts as a compressor. The ammonia circulates completely around the circuit, from the evaporator through the absorber and generator to the condenser, whereas the water only circulates between the absorber and the generator.

In the condenser, the ammonia loses heat and condenses. The liquid ammonia is then passed through a flow valve to the evaporator. Here the pressure is sufficiently low for evaporation to occur, due to the latent heat being extracted from the evaporator surroundings. The ammonia vapour enters the absorber where it is absorbed by the water with an accompanying release of the heat. The concentrated solution can now be passed easily to the high-pressure region of the generator using a pump. As the absorption process has effectively 'compressed' the volume of vapour, this is not a compressor, but merely a circulating device requiring little energy (McMullan, Morgan, Murray 1977). In the generator, the water and ammonia are again separated using heat energy as the energy present at the exhaust of a thermal equipment. The water flows back to the absorber through a flow control valve and the ammonia vapour passes directly to the condenser. Thus, the absorption refrigeration cycle is essentially combination of a heat engine and a vapour compression cycle combined. The technology allows the same energy service as the conventional electric pumped cooling system with only one-

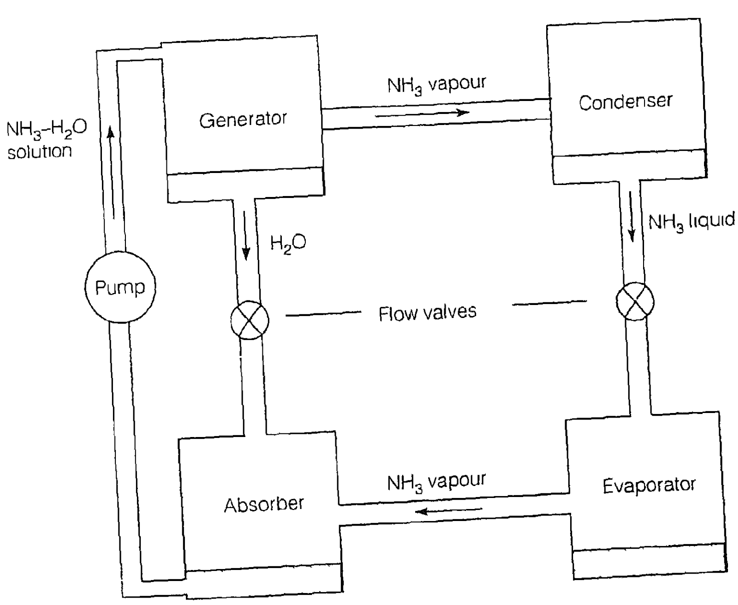


Figure 4. Absorption refrigeration cycle source
Source. McMullan, Morgan,, Murray (1977)

fourth of the electricity consumption and with the significant environmental advantage of avoiding the use of chlorofluorocarbons, since it uses ammonia or lithium bromide as the cooling agent.

In these circumstances, small scale electricity generation can be performed in a thermodynamic cycle and the heated exhaust air can be used directly in the absorption pump or indirectly through the production of steam. Commercial cooling systems are lower than 5000 TR/hour which is compatible with the generation of less than 10 MW of electricity. Due to the small size, as compared with central power stations, the economy of scale in the investment is an important adverse factor.

Absorption air-cooling systems are being installed in the US in systems that use gas turbines or diesel engines for the generation of electricity. Gas turbines are less efficient than diesel engines for this range of size but have a longer operational life. Initial investments in the US are very similar for both options, but this is not the case in developing countries. Diesel engines are an old technology and some developing countries have the capability to produce or assemble such engines. Gas turbines are a new technology for them and almost all the equipment has to be imported with a consequent increase in price due to taxes, transportation, and outside assistance.

2.5 Case-studies for Brazil

Thermoelectricity is responsible for a very small fraction of electricity generated in central power stations in Brazil. There are a few coal-based steam turbines being used in the southern state of Rio Grande do Sul. Such units are smaller in size when compared to the international market (around 300 MW per unit) and the total installed capacity adds up to 1500 MW. The efficiency is not good—28% on an average (BEN 1992)—and they have to compete with hydro-electricity since they are connected to the major grid system which links the south/south-east and the central-western regions of Brazil.

There are three other medium size oil-fired steam turbine units (200–500 MW) in operation in South-east Brazil. They also complement hydro-electricity and, in years of normal rainfall, they are used for less than 10% of the time. This is a little less than the coal-based stations which run with a load factor of 20% under the same circumstances (Eletrobras 1992). In the Amazon, there is more scope for thermo-electricity. Isolated systems are mainly supplied by single cycle gas turbines using a blend of light fuel oil/diesel or diesel engines coupled to generators (Poole, Ortega, Moreira 1990). On an average, thermo-electricity supplies only four per cent of the total electricity demand (BEN 1992).

It is only in the last six years that interest in the installation of more thermo-electric units based on fuels other than coal has appeared. For central power stations, the largest project being considered is the installation of a 450 MW complex fuelled with natural gas from Bolivia and which should be installed in Bolivia, near the Brazilian border, for exporting electricity to the south/southeast/central-western linked grid.[1] The project was the result of a contract between Brazil and Bolivia. The interest of Brazil lies in receiving the electricity and not with the technology used. There is no clear informa-

[1] Eletrobras. 1989. *Plano Decenal* 1990/1991, Rio de Janeiro, Brazil: Ministerio das Minas e Energia.

tion about the equipment that shall be used but there are claims that single cycle gas turbines may be used (SNE 1992).

Another project under discussion is the proposal of the Companhia Energetica de São Paulo to install two steam-based thermal plants (700 and 350 MW) near oil refineries to run with very heavy oil[1] (CESP 1989). Another possibility is the proposal to convert the oil-based steam thermal plant in the state of São Paulo (475 MW) to a combined cycle, with the additional installation of gas turbines (CESP 1989). This project would require an investment of one billion dollars and would increase the plant output to 1200 MW.[2] This proposal has been much criticized, since the existing plant is about 30 years old and was designed to use high pressure steam (110 bars) which cannot be used in a combined cycle.

A programme which is being seriously executed is the production and export of electricity to the grid by the sugarcane industries. The sugar and ethanol mills, installed in large numbers (359 units)[3] to supply the Programa Nacional do Alcool (PNA) since 1975, were designed to use very simple technologies, including that for the production of electricity and steam. Since the beginning of the PNA, mills were equipped with steam boilers fuelled mainly by sugarcane bagasse and, when necessary, with wood. Low pressure steam is required in large amounts for the production of sugar and as much as 500 kg of steam is consumed during the processing of one tonne of sugarcane. Since steam has to be produced for the distillation process, most of the mills were designed to produce steam at a pressure of 21 bars. This means that the medium pressure steam can be used initially for providing mechanical power and the low pressure escape steam for heating the distillation columns. Until a few years ago, there was no reason to be efficient since the sugarcane residue had little or no value. Low efficiency boilers are able to provide up to 20 kWh/tonne of cane and 500 kg of steam/tonne of cane, which is enough to run the processing plant (SNE 1992).

Technology is available for the production of much more electricity per tonne of cane. A recent evaluation carried by Eletrobras and Copersucar[4] concluded that steam turbines burning sugarcane bagasse can produce as much as 83 kWh/tonne of cane, as well as all the steam required for the sugar and/or alcohol processing. This study investigated six alternatives to enhance electricity production from sugar mills in São Paulo state. The simplest one is the reduction in the amount of steam required for sugarcane processing. Steam reduction from 465 kg/tonne of cane to 332 kg/tonne of cane was analysed as feasible. The second alternative proposes cogeneration with steam extraction at the limit of steam pressure required for the process, using boilers from 21 to 80 bars of pressure. The third alternative foresees the use of condensing-extraction steam turbines with the use of 100% of the bagasse and other sugarcane residues during the season, with steam pressure of 21 to 80 bars. The fourth alternative is the same as the third and includes the burning of bagasse produced from stillage fermentation. The fifth alternative is also the same as the third with the burning of dry stillage, and the sixth alternative deals with a completely different technology—gas turbines (Section 2.6). Investment costs

2 Reconstrucao da Usina de Piratininga. 1989. Tecnoplan. São Paulo.
3 Copersucar. 1992. Report 'Agroindustria de Cana-de-Agucar'. São Paulo, Brazil.
4 Convenio Eletrobras-Copersucar. 1991. Geracao de Energia Eletrica em Usinas e Destilarias. São Paulo, Brazil.

range from US $1300–1800/kW produced using steam turbines, which means that an investment of up to 20 million dollars is necessary to take full advantage of the efficient use of the sugarcane bagasse and residues available in a mill processing 300 tonnes of cane/hour (650 000 litres/day of ethanol during the season). This is a significant investment since a conventional mill of this size requires a total investment of about 40 million dollars. The increase in investment is high but the study concludes that further electric generation is cost-effective if electricity can be sold to the grid at US $55/MWh (US $48 for the generation and US $7 for the avoided transmission investments). Total electricity production from sugarcane and residues using steam turbine technology can be as large as 19.2 tWh or about 10% of the total electricity consumed in Brazil today.

2.6 Advanced technology status

Another possibility is the use of gas turbines using sugarcane, bagasse, and residues as fuel. This technology requires the gasification of biomass, as a front-end process, to provide adequate fuel to the turbine. There are no commercial installations in the world based on this technology but research is underway and projects are being developed to use its potential.

Biomass gasification, like coal gasification, is by no means a novel concept, as fuel gas has been manufactured from coal for about two centuries. Throughout the nineteenth century and well into the twentieth, the most familiar fuel gas was 'town gas', a combustible mixture of hydrogen and carbon monoxide produced from coal, used for lighting and cooking. After 1950, the most successful fuel gas has been natural gas and its upsurge has been a key reason why some markets for coal have dwindled. In the 1990s, although the competition from natural gas has become even more intense, fuel gases from coal and biomass are gradually edging back into contention.

A variety of large scale coal gasification units have recently been assembled and become operational. In 1975, British Gas, in UK, constructed a commercial scale prototype gasifier in Westfield, Scotland. The reactor operates at a high pressure (23 bars) and uses pure oxygen and steam to gasify 550 tonnes/day of coal. The performance has been quite good and the unit was used mainly as a test bed for different trials for various applications. A Rolls Royce SK 30 gas turbine was installed in 1986 and supplied electricity to the South Scotland Electricity Board (Patterson 1990).

An international oil company, Shell, began its own coal gasification programme in 1972. A large experimental unit, with a capacity of 150 tonnes/day, started operation in 1978 at Shell's Hamburg refinery in ex-West Germany. It operates at 23 bars and also uses pure oxygen. A full scale commercial demonstration unit was completed in 1987, at Shell's Deer Park near Houston, Texas, with a capacity to gasify 250 tonnes/day of bituminous high sulphur coal. The unit is in operation, and according to Electric Power Research Institute (EPRI), it has met and exceeded all environmental requirements. Shell has always been interested in the production of electricity as an end-use of fuel gas. Thus it decided to install, at Buggenum, in the Netherlands, a plant, able to gasify 2000 tonnes/day of bituminous coal for generating 285 MWe from a gas turbine generator and 130 MWe from a steam turbine generator (combined cycle). Net efficiency of the plant should be 43.2% (Patterson

1990). From Shell's experience, they believe that a new commercial unit with 400 MWe will cost US \$1400–1500/kW (the existing US dollar rate in 1990).

Another company, Texaco, is also very interested in the electricity generation, and its gasifier design was used as part of the Cool Water project. Under this project, 1000 tonnes of coal per day were gasified at high pressure, using oxygen and a combined cycle power plant. An EPRI study, published in late 1987, suggested that electricity from a mature commercial plant with the same technology would be able to sell electricity 10% cheaper than a conventional coal-fired plant with the same emission quality. The planned experimental programme was completed in 1989 and was shut down, since its overall fuel efficiency was only 32% and it could not compete economically with other generating capacity available in the region (Patterson 1990).

The Dow Chemical Company also has a coal gasifier in operation in Plaquemine near Baton Rouge, Louisiana. The gasifier feeds a combined cycle power plant which generates 161 MW of net power. The gas turbine runs with producer gas, natural gas, or blends of both and has been able to comply with federal environmental standards (Patterson 1990). Other projects are under consideration, using similar technology or adding a major breakthrough like the one proposed by H & G Engineering and the candidate for installation at the Nynas Energy Chemical Complex AB, south of Stockholm. The breakthrough is the passage of the hot producer gas through a water quench, and then into a so-called 'shift expander' to promote the 'shift reaction': $CO + H_2O \rightarrow CO_2 + H_2$. This is an exothermic reaction which reduces the steam content of the fuel gas avoiding water condensation during gas expansion. Again, the temperature increase raises the pressure enough so that the gas can be fed through an 'expander', like the turbine stage of a gas turbine producing extra electricity (Patterson 1990).

Biomass gasification, in principle, is technically more easily achievable than coal gasification (Larson 1991), but not so well developed. The major reason is that until recently biomass was envisaged as a low quality fuel, with a tendency for its participation in the primary energy matrix to decline as the countries develop. Commercial biomass was poorly used and non-commercial biomass was important as a source of energy only in the Third World, where technical competence and financial constraints impose serious limitations for development of new technologies. Important differences with respect to coal gasification are the use of air-blown instead of oxygen-blown gasification and probably the use of a steam injected gas turbine instead of a combined cycle. The sensitivity to scale costs of oxygen plants and conventional combined cycles recommends the other options. Figure 5 depicts the cost comparison between coal gasifiers/gas turbine power plants (Pitrolo, Grahan 1990). The upper curve represents technology like that of the Cool Water Commercial Demonstration Plant that uses a Texaco entrained-bed gasifier, cold gas clean-up, and a combined cycle. The lower curve represents systems using air-blown fixed-bed gasification with a hot gas clean-up and either a combined cycle or steam-injected gas turbines. The points on this curve are calculated costs for specific plants using integral numbers of gasifiers and commercial gas turbines. Also, while the gas exits, the gasifier must be cleaned. Doing this would not require developing advanced hot sulphur removal

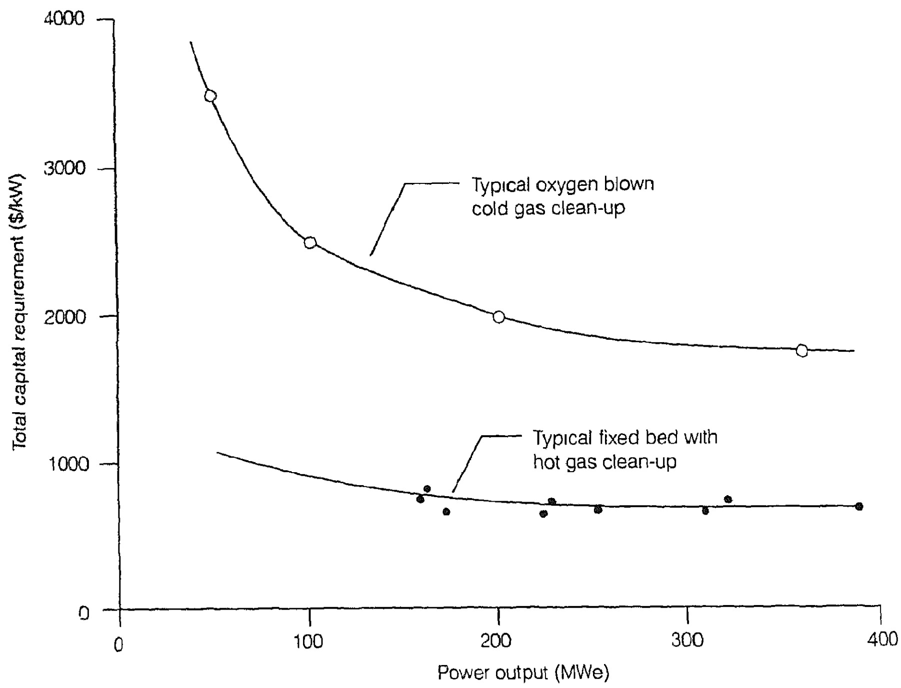


Figure 5. Cost comparison between coal gasifiers and gas turbine power plants
Source. Pitrolo, Grahan (1990)

technologies (as required for coal), because most biomass contains negligible sulphur. Furthermore, the looser molecular structures of biomass compared to coal makes it more reactive and easier to gasify (Figure 6) so that fixed bed and fluidized bed gasifiers, which operate at lower average temperatures than some of the gasifiers used for coal, can provide essentially complete carbon conversion and high gasification efficiency (Larson, Svenningasson, Bjerle 1989).

There are four major projects under development to make the biomass gasification gas turbine (BGGT), a commercial product. Ahlstrom, a Finnish producer of biomass gasifier, plans to build a 6–10 MWe BGGT cogeneration demonstration plant in Sweden.[5] The gasifier would be of the pressurized fluidized bed type. The Department of Energy in the US has selected one pressurized bubbling fluidized bed gasifier developed by the Institute of Gas Technology to be assembled in Hawaii, using sugarcane bagasse (Babu 1990). In the US, the Vermont Department of Public Service was also quite active in 1990/1991 overseeing the installation of a gasifier and a gas turbine unit that would use wood residues as fuel. Under this project, GE carried out a complete experiment on the compatibility of the gas fuel characteristics and the performance of the gas turbine simulator in 1992 (Wall Street Journal 1992). The fourth project is described in the next section.

[5] Ahlstrom Corporation, Skydkraft A B. 1990. Skydkraft AB, Sweden and A Ahlstrom, Finland Goes Ahead with Unique Gasification Process. Press release, 7 November 1990. Helsinki, Finland; Malmo, Sweden.

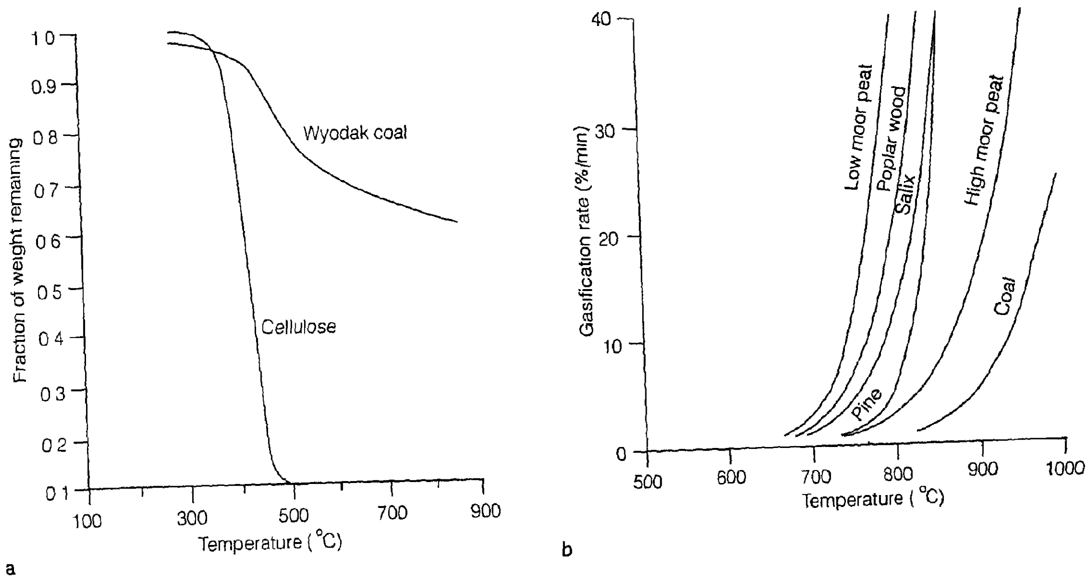


Figure 6. Comparison of gasification characteristics of biomass and coal. **a** Weight loss as a function of pyrolysis temperature for coal and cellulose and **b** Gasification rates for different feedstocks
Source. Larson, Svenningsson, Bjerle (1989)

2.7 Advanced technology in Brazil

In Brazil, a consortium of private and public companies prepared a proposal to build a wood gasifier coupled with a gas turbine to produce 20-30 MWe. The project received a grant from the GEF and is presently in second Phase, which is the detailed engineering project and the removal of major technological bottlenecks. These include small modifications on the gas turbine to run with low BTU gas (1000 kcal/Nm^3) and the choice of an appropriate gasifier and gas clean-up system to provide fuel gas under the severe specifications of the gas turbine manufacturer. The second phase of the project should be completed in 1994 and if a successful detailed project can be prepared, US $23 million will be available, as a GEF grant, for its construction. Total cost is estimated to be around US $2500/kWe for the first demonstration unit (Queiroz 1992). This means that total investment cost for the generation of 20 MWe will add to US $50 million, with the balance of the money provided with capital from the involved companies (Shell do Brasil, Companhia Vale do Rio Doce, Companhia Hidrelitrica do Seo Francisco, and the Electric Sector Board). GE is preparing the gas turbine modifications and Bioflow, a Finnish Consortium of the Ahlstrom and Skydkraft companies, and Studvick, a Swedish company, are designing two different gasifiers (Esteves 1992).

A recent evaluation carried out by the major ethanol producers organization in Brazil (Copersucar) and the Electric Sector Board concluded, after analysing six different alternatives for electric power production, that the gas turbine alternative requires less investments and allows the production of 40% of the total electricity consumed in Brazil in 1991 (refer Footnote 4).

Advanced technology is also being used in Brazil for cogeneration of electricity and air cooling. An installation using such technology was completed in a shopping centre in Rio de Janeiro, using a Caterpillar gas turbine and an air cooling absorption pump. A project is under development for a large office area of the Banespa Bank (BB) in the city of São Paulo. To provide air cooling to 240 000 m^2 of space, a system with a total heat capacity of 4000 TR fed with the heat exhausted by a set of two 3 MW gas turbines (6 MW) should be used (BB 1991). Another shopping centre under construction in São Paulo is interested in the technology. A pre-feasibility study concluded that the total cost for the installation of 1800 TR plus the generation of 3000 kWe would reach US $4–6 million.[6] Even with the lowest price of natural gas (13 cents per Nm^3 under a take or pay contract), the payback period of four to seven years, is a long one by private entrepreneurial criteria. The reasons for the poor economic feasibility are: (i) the technology is very new and the first few units will be more expensive; (ii) electricity cost during off-peak hours in Brazil is low (four cents/kWh) and, even charging heavily on price during the peak period, the average cost is low (eight cents/kWh) for users who buy power at middle voltage (13.8 kV).

2.8 Institutional issues in Brazil

The interest of the public authorities in the use of cogeneration is growing. Shortage of public money to expand the supply of electricity is the major motivation. A recent document prepared by the Secretary of Science and Technology of the State of São Paulo claims that cogeneration using natural gas as a fuel is reliable, less costly than adding of new central power stations, requires a short time to be operational, can be installed near the major consumers in the cities, has good efficiency, and causes less impact to the environment (Ennes, Carmo 1992).

Another document raises several institutional issues that must be solved to stimulate cogeneration.[7]

(i) *Tariff rate*—the acquisition price of excess electricity sold to the grid should be an object of negotiation though it cannot be lower than US $42/MWh nor higher than the long term marginal cost of the interconnected grid system (presently around US $53/kWh).

(ii) *Continuous supply*—since most Brazilian electricity is supplied from hydro sources, the major utilities would like to sell their energy as base loads and to rely on private cogenerators only during the dry season and/or in the critical rain years. This situation does not favour private producers and does not fit the profile of electricity generated by them. Thus, minimum load factors should be guaranteed in contracts to foster cogeneration.

(iii) *Existing legislation*—the first regulation on private cogenerators set by the Federal Control Board (DNAEE) was in 1981. Since then few contracts have been signed. The further regu-

[6] MHA Engenharia e Projetos Ltda. 1992. Avaliageo Ticnico Econtmica para Utilizageo do Sistema de Cogerageo de Energia para o Shopping Plaza Sul-SP. São Paulo, Brazil.

[7] Subcomisseo de Usos do Gas Natural. 1992. Proposta de Resolugeo Provissria para Alterageo de Portarias do DNAEE. São Paulo, Brazil: Governo de São Paulo.

lations issued do not guarantee minimum load factors and there is no clear methodology for the definition of avoided costs on central power station construction due to electricity supply by cogenerators. The time horizon of contracts is also not regulated in order to guarantee return on investments.

The necessity for regulations more favourable to cogenerators is obvious. The potential for natural gas based cogenerators is very significant. A conservative estimate based on data from 1985 claims that 13 TWh (6.5% of the electricity consumed in Brazil in 1991) could be produced (Ennes, Carmo 1992). Cogeneration potential by the sugar/ethanol industry can be as high as 100 TWh (Moreira, Goldemberg 1988).

Even in the existing difficult context, cogenerators from the sugar/ethanol industry are selling excess electricity to the grid. The largest supplier, Companhia Agucareira Vale do Rosario, sells to the grid 2.3 MW during the season, at a price of US $21/MWh. The surplus electricity is derived from sugarcane bagasse burnt in a 21 bar steam boiler. An agreement between the three major utilities of the state of São Paulo will set the acquisition electricity price equivalent to the long range marginal cost. The cogenerator is willing to invest US $2.5 million to upgrade the boiler to 42 bars and then sell 5 MW if the price is adjusted between US $45–55/MWh (Gazeta Mercantil 1992).

2.9 Environmental issues

The principal gas (GHG) of which Brazil is an important contributor in the world is CO_2 and the largest source of CO_2 emissions in the country is from clearing of forest land for other uses. Despite the preponderance of deforestation on CO_2 emissions, it is important to search for possibilities of its reduction from fossil fuel.

Total CO_2 emissions from the combustion of fossil fuel in 1990 reached approximately 57 mtoc. To this value, we have to add CO_2 produced from biomass when burned for energy production. A rough evaluation suggests that 9 mtoc have to be added to the earlier figure yielding total carbon emissions of 66 mt in 1990 (Moreira *et al. 1992)*.

CO_2 emissions for electricity generation in Brazil are very low when compared to other developing countries; and is about 9 kg/MWh against a world average of 170. Thus the impact, on the electricity profile, of new thermal central power stations or cogenerators, (though they represent a significant change) at the margin of the electricity profile, will be negligible for a long time. Even so, if it is possible to develop a policy that will fulfil other major requirements and can be less aggressive to the environment, it should be pursued.

Cogeneration can be practised in Brazil with a net benefit to the environment. Industries in Brazil used 8 mtoe of oil and 4.9 mtoe of firewood (Table 1). With cogeneration, mainly with natural gas, we observe a decline in the amount of fuel oil and firewood consumed. Remembering that fuel oil has an emission rate of 72.6 tonnes of CO_2 and natural gas only 50.6 tonnes of CO_2 per 1012 J of burned fuel, this substitution implies CO_2 abatement. The present use of firewood also plays an important role, since around 50% of it is due to deforestation, contributing thus to CO_2 emissions (Moreira *et*

al. 1992). Firewood based industries will not be good candidates for cogeneration, because of the instability of supply and growing public and private awareness against deforestation. Sugarcane bagasse, on the other hand, is a very good source that can be used by cogenerators in the sugar/ethanol industries. As a completely renewable energy source, its emissions of CO_2 are negligible. Overall CO_2 emissions from cogeneration, then, will not increase above the present industrial level. However, these units would need to improved fuel efficiency if they are to be cost-effective.

The high technologies being offered world-wide for generation of electricity are always concerned with reduction of local and global pollution (ISES 1992).

2.10 Conclusion

Cogeneration is an excellent method to improve efficiency in the use of energy. Due to several difficulties, the state owned electric sector is starting to accept cogenerators as possible solutions to attract private capital for infrastructure investment. Cogeneration is being commercially practised in the US. Several projects are being implemented in Brazil, where a few plants are already in operation. The largest potential cogenerators have been identified as the sugar and ethanol industries followed by other industrial plants which use large amounts of process heat. The former should use sugarcane bagasse and field residues as their source of primary energy, and the latter should rely on natural gas. Renewable energy sources like bagasse will help to improve the quality of the environment at a global level and their use should be encouraged either through grants or preferential aid from international financing. Natural gas will replace fuel oil in the potential cogenerators' industries with a positive impact on global environment too, since its CO_2 emissions are lower than oil for the same amount of energy consumed (Moreira *et al.* 1992).

Finally it is important to observe that the utilization of biomass as a source of energy is the only way to avoid deforestation. The development of commercial biomass gasifiers, coupled with gas turbines, is a technology fully discussed due to its prevention of deforestation. Some of the several technologies discussed should become extensively commercial before the end of the century.

REFERENCES

1 Babu S. 1990. Personal communication II. Chicago: Institute of Gas Technology.

2 BB. 1991. Internal report. São Paulo, Brazil: Banespa Bank.

3 Bemis G R *et al.* 1989. Technology characterization: final report. Staff Issue Paper 7R. Sacramento, California: Energy Resources Conservation and Development Commission.

4 BEN. 1992. Internal publication. Brasilia, Brazil: Ministirio da Infraestrutura, Balango Energitico Nacional.

5 Broekhuizen A L, van Lavieren R R, Kamming P. 1988. A gas turbine cogeneration plant with a gross electrical efficiency of over 50%. International Gas Turbine Conference and Exhibition, Dusseldorf, West Germany, 8–12 June 1988.

6 CESP. 1989. Paulina Thermal Power Plant Technical Specification. São Paulo, Brazil: Companhia Energética de São Paulo.

7 de Biasi V. 1991. LM 6000 dubbed the 40/40 machine due for full-load tests in late 1991. *Gas Turbine World* **20**(3): 1620.
8 de Queiroz L C. 1992. Personal communication to Moreria J R. São Paulo, Brazıl: BRASCEP.
9 Eletrobras. 1992. Monthly report (Boletim de Mercado e Carga Prspria). Rio de Janeiro, Brazil: Eletrobras.
10 Ennes S A W, Carmo M E M. 1992. Cogeracão a gas natural—texto para Subcomisseo de usos do gas natural. São Paulo, Brazil: Governo de São Paulo.
11 EPRI. 1986. Technical Assessment Guide 1: Electricity supply—1986. Palo Alto, California: Electric Power Research Institute.
12 Esteves J M. 1992. Personal communıcation. Brasılia, Brazil: Ministério de Ciência e Tecnologia.
13 FERC. 1987. Notıce of technical conference on the regulation of ındependent power producers—EL **87-67-000.** Washington, DC: Federal Energy Regulatory Commıssion.
14 Gazeta Mercantil. 1992. 14, 15, and 16 November 1992: 15-16.
15 Geller H S, Moreira J R. 1992. Brazıl's National Electricity Conservation Program (PROCEL): progress and lessons. Demand-side Management and the Global Envıronment Conference, Arlington, VA, 22-23 April 1992.
16 GERE. 1992. Relatorio de Atividades do Grupo Executivo do Programa Nacional de Racionalizacao da Producao e do Uso de Energia. Brasilia, Brazil: Secretaria de Ciêncıa e Tecnologıa/PR.
17 ISES. 1992. Solar energy solutions for an environmentally sustaınable world. Final report for the United Nations Conference on Environment and Development. Victoria, Australia: International Solar Energy Socıety.
18 Larson E D, Svenningsson S, Bjerle I. 1989. Biomass gasification for gas turbine power generation: electricity end-use and new generation technologies, and their planning implications . *In* Johansson T B, Bodlund B, Williams R H (eds). *Electricity: Efficient End-Use and New Generatıon Technologies and their Planning Implications*. Lund, Sweden: Lund University Press.
19 Larson E D. 1991. Biomass-gasifier/gas-turbine cogeneration in the pulp and paper industry. Princeton, NJ: Center for Energy and Environment Studies, Princeton University.
20 Macchi E. 1990. Power generation (including cogeneration). Draft manuscript. Milan: Polytechnic University.
21 McMullan J T, Morgan R, Murray R B. 1977. *Energy Resources and Supply*. Chichester: John Wiley & Sons.
22 Moreira J R, Goldemberg J. 1988. Programa Nacional do Alcool em 1988 (preprint **PE-EN-001/88**) Brazil: Instituto de Eletrotécnica e Energia.
23 Moreira J R, Januzzı G M, Poole A D, Zylbersztajn D, Fries J. 1992. Estimation of Asia's and Brazil's contribution to GHG emıssions and policy responses for the minimization. International Centre of Theoretical Physics, Workshop and Conference on 'Global change and environmental considerations for energy system development', Trieste, Italy, 21 April-8 May 1992.
24 Patterson W C. 1990. Coal-use technologıes in a changing environment. *Financial Times Business Information*, New York.
25 Pitrolo A A, Grahan L E. 1990. DOE activities supporting IGCC technologies. Proceedings of the Conference on 'Integrated gasification combined cycle plants for utility applicatıons', Chla, Canadian Electrical Association, Montreal, 1990.
26 Poole A D, Moreira J R. 1979. Energy problems in Brazıl with a closer look of the ethanol-methanol problem São Paulo: Instituto de Fmsica da Universidade de São Paulo.
27 Poole A D, Ortega O E, Moreira J R. 1990. Energia para o Desenvolvımento da Amazonia (contribution for the project UNDP/SUDAM/SUFRAMA/BASA). *In* Macrocenarios da Amazonia 2010, Braselia, Brazil.
28 Poole A D, Moreira J R. 1992. CO_2 emission abatement in Brazil. Brasilia, Brazil: Secretaria de Cienciae Tecnologia/PR.
29 Sathel. 1985. Usina Termo e Hidroelitrica SA—Projeto Sathel. UTE Boca do Acre 1.
30 SNE. 1992. Internal publication. Brasilia, Brazil: Ministry of Infrastructure, Secretaria Nacional de Energia.
31 Wall Street Journal. 1992. G E researchers say waste from plants can be used as fuel for gas turbines. *Wall Street Journal*: 6 May 1992.
32 Wilhams R H, Larson E D. 1988. Aeroderivative turbines for stationary power. *Annual Review of Energy* **13**: 429–489
33 Williams R H, Larson E. 1989. Advanced gasification-based biomass power generation and cogeneration Internal publication. In press.

BIBLIOGRAPHY

1 EEI. 1992. *Statistical Yearbook of the Electric Utility Industry*. Washington, DC: Edison Electric Institute.
2 US DE. 1984. Industrial cogeneration potential 1980-2000—applications of four commercially available prime movers at the plant size (DOE). Washington, DC: United States Department of Energy.
3 Williams R H, Larson E D. 1989. Expanding roles for gas turbines in power generation. *In* Johansson T B, Bodlund B, Williams R H (eds). *Electricity: Efficient End-Use and New Generation Technologies and their Planning Implications*. Lund, Sweden: Lund University Press.

Technology transfer in the Indian context

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1 Introduction

1.1 Technology transfer

The Conventions on Climate Change and Biodiversity adopted in Rio in 1992 envisage technology transfer for developing countries. The developing countries are expected to meet certain commitments conditional to these transfers being made, which would necessitate an assessment of the prevalent conditions (in which such transfers would be made) in that particular country. This paper commences with a discussion of the barriers preventing an effective transfer under Indian conditions till now, a description of recent policy reforms meant to facilitate technology transfer and foreign direct investment (FDI), and finally examines the options of cogeneration and efficient lighting from a CO_2 abatement perspective. The cogeneration and efficient lighting options were selected for detailed analysis as there is a need to facilitate technology transfer. Cogeneration has been widely recognized as an effective supply side option to reduce CO_2 emissions per unit of energy generated. On the other hand, efficient lighting has an enormous potential to cut down end use energy consumption. This is particularly so in Indian case, where the electricity system is characterized by well defined evening system peaks.

Transfer of technology can occur from a supplier to a recipient by various mechanisms both commercial and non-commercial. The principal routes of commercial transfer of technology are:

- (i) FDI in a host country, subsidiary or a joint venture;
- (ii) licensing of industrial property rights;
- (iii) technical assistance;
- (iv) sale, importation, installation, and servicing of machinery and equipment and other capital goods; and
- (v) franchising of consumer goods and services.

The effectiveness of such transfers would be dependent on the prevalent conditions within the recipient country, apart from the stage of technological development, characteristics of end-users, and

potential for absorption and diffusion within the recipient country, among other factors. Some of the barriers in the past identified by Indian collaborators are listed below.

(i) Import restrictions on technology.
(ii) Limited depth of technology transfer.
(iii) Delays in approval.
(iv) Royalty limit of five per cent on value added (with exceptions for highly sophisticated technologies) which is considered restrictive by international standards apart from the limitation on the contract duration.
(v) Firms also disliked the control exercised by the Indian Government. In particular they disliked the obligatory sub-licensing requirement of Indian law according to which the Indian party could sub-license the technology on mutually agreed terms.
(vi) Procedures to be followed were considered complicated due to reasons ranging from bureaucratic detours, administrative problems, and varying approval procedures.
(vii) Profitability of the technology transfer may be under question due to the tax burden, the customs duties on imports and the potential of better payments for these transfers.

A study of the import substituting regime by Desai in the eighties (Sridharan 1991) indicated the features listed below.

(i) The extent of foreign technology transfer and FDI had been negligible in comparison to other less developed countries (LDCs), as measured by the number of technical collaboration agreements.
(ii) Extent of outflow from India on account of profits and dividends was lower than other LDCs.
(iii) Shallowness of Indian technology collaborations.
(iv) Prevalent restrictions on FDI and technology import, in the form of restrictions on royalties, duration, equity participation, and absence of large lumpsum payments. This had reduced outflow of foreign exchange simultaneously decreasing the depth of technology transferred.
(v) It was found that technology import did not deter indigenous research effort and importers of technology tended to do more research.
(vi) Multinational corporations were not the major sources of the technology transferred so far.
(vii) The highly sheltered import-substitution industrialization regime led to a lack of competitive pressure to upgrade existing technology.
(viii) The prevailing industrial policy discouraged the existence of the kind of firm which could effectively negotiate and assimilate technology.
(ix) The study also focused attention on government expenditure on industrial R & D and their inability to generate the requisite amount of commercially relevant technology and income from the sale of such technologies.

These study findings assume significance in the present altered environment which is meant to encourage and/or facilitate technology transfer. These liberalization measures introduced by the government have, to a great extent, removed the obstacles have discouraged such transfers till now.

1.2 Transfer of technology regulations

In India, transfer of technology regulations relates to major policy areas such as technology; industry, and trade. Till recently, entry of foreign capital and technology into India was allowed provided that they met certain conditions.

Undertakings, either Indian or foreign, had to conform to the general requirements of the Industrial Policy. Foreign concerns were permitted to earn profits subject to regulations common to all other enterprises functioning within the country. Foreign exchange considerations determined the freedom to remit profits and repatriate capital. Furthermore, the major interest in ownership and effective control of an undertaking were to be in Indian hands.

1.3 The Technology Policy Statement (1983)

The Technology Policy (1983), which laid down the guidelines towards technology acquisition by India, encouraged self reliance but did not imply self-sufficiency. According to it, import of technology and foreign investment were to be on a selective basis where need had been established. This was for cases where the technology did not exist within the country, and time required to develop the technology would delay achievement of development targets. Absorption, adaptation, and subsequent improvement of imported technology were to form part of the R & D commitment. This policy also incorporated encouragement of in-house R & D. The Department of Science and Technology (DST), in collaboration with the Directorate General of Technical Development (DGTD), had in operation a scheme whereby recognized R & D units of industrial enterprises received fiscal concessions and other incentives.

According to the technology policy, based on the access of industry to foreign technologies, industries were categorized as those where: indigenous technology was adequate and hence no foreign investment/licensing was to be allowed; foreign technology was necessary but tightly held, hence, only licensing was to be allowed; both licensing and direct investment would be allowed.

1.4 Policy reforms facilitating technology transfer and foreign direct investment

1.4.1 Technology policy reforms

The draft paper on technology policy (1993) points out the need to adhere to international quality systems, apart from preserving the environment. In sections relating to the environment, it is pertinent to note that promotion and use of cleaner technologies are aimed at. It also aims at ensuring access to such technologies abroad. Among the identified thrust areas are energy related technologies, including those for alternative fuels, renewable/non-conventional sources, and energy conservation technologies.

1.4.2 Industrial policy reforms

The new industrial policy of July 1991 has been instrumental in substantially deregulating the industrial sector and liberalizing foreign investment and technology imports. The reforms would have far-reaching consequences for industry by shifting from a regulatory and protected regime to a free market oriented competitive environment.

Some of the changes in industrial policy are given below.

(i) Dereservation of industries for the public sector with the list of reserved industries being reduced from 18 to 8. Industries which would continue to be reserved are in areas where security and strategic concerns dominate.

(ii) Abolishing industrial licensing for all projects, except in 18 industries where strategic or environmental concerns are paramount or where industries produce goods with exceptionally high import content.

(iii) The MRTP Act[1] has been amended so that the need for prior approval by large companies for capacity expansion or diversification has been eliminated, to enable Indian firms to become large enough to compete effectively in global markets.

(iv) The requirement of phased manufacturing programmes has been discontinued for all new projects. This had been in force for a number of engineering and electronic industries in an attempt to quicken the pace of indigenization in manufacturing.

(v) Areas reserved for the public sector have been narrowed down to eight as compared to the earlier 17, and greater participation by the private sector permitted in the core and basic industries.

(vi) Government clearance for location of projects has been dispensed with, except in the cases of 23 cities with a population of more than one million.

(vii) Small scale industries have been given the option of offering up to 24% of their shareholding to large scale and other industrial undertakings, thus allowing them greater access to capital and technology.

(viii) A national renewal fund has been set up with a corpus of Rs 200 crore to ensure that the costs of technological change and modernization of industry are not borne by the workers.

Similarly, industrial policy has been altered to promote the inflow of FDI. For a specified list of high technology industries and high investment priority industries, firms will now receive automatic approval to make foreign technology agreements within certain guidelines. This list has been further altered to increase the number of industries which could obtain direct approval. Earlier, the hiring of foreign technicians and testing of indigenous technology abroad required case by case approval. This, however, will not be required any longer. The limit of foreign equity holdings has been raised from 40 to 51% in a wide range of 34 priority industries. However, foreign exchange outflow on account of dividends on additional equity will be balanced by export earnings over a period of seven years

[1] The MRTP Act refers to the Monopolies and Restricted Trade Practices Act.

from the commencement of production. Foreign equity participation has automatic approval and will be cleared by the Reserve Bank of India. Foreign technology agreements have also been liberalized for the same industries allowing them to negotiate the terms of technology transfer based on their own commercial judgement and avoiding the need for government approval for both hiring of foreign technicians and the testing of indigenous technologies abroad. The procedures for investment in non priority industries have been streamlined. The Foreign Investment Promotion Board (FIPB) has been established to negotiate with large international firms and to expedite the clearances required. The FIPB also considers individual cases involving foreign equity participation over 51%. Technology imports for priority industries will be automatically approved for royalty payments up to five per cent of domestic sales and eight per cent of export sales or for lumpsum payments of one crore rupees.

The response to the new industrial policy has been very encouraging. After the announcement of the new industrial policy, although registrations have been discontinued, the filing of industrial entrepreneurs memoranda has replaced it. The number of investment approvals given in 1991 has risen to 5538 from 3335 in 1990. The figure for 1991 includes 3095 industrial entrepreneurs memoranda filed under the new policy, which would have earlier required letters of intent or industrial licenses. 3897 investment proposals were cleared between the announcement of the new policy on 24 July 1991 and 31 January 1992. During the same period, 505 foreign technology import agreements were also approved.

Changes brought about in policies toward FDI have also evoked a strong positive response from foreign companies. In 1991, a total of 244 cases of foreign equity participation with a proposed equity investment of $504 million was approved. In the previous three years—1988, 1989, and 1990—the total inflow of foreign equity was $95 million, $120 million, and $50 million, respectively.

1.4.3 Trade policy reforms

Certain initiatives have also been introduced to provide an environment aimed at reducing the degree of regulation and licensing control on foreign trade. Permission to import capital goods was given without clearance from the indigenous availability angle, provided this import was fully covered by foreign equity or was up to 25% of the plant and machinery, subject to a maximum of two crore rupees. Export and trading houses and Star Trading houses have been permitted a larger range of imports. 51% foreign equity has now also been allowed in trading houses.

1.4.4 Patent protection and technology transfer

The nature and extent of intellectual property right (IPR) protection extended to technologies within a country is important from the viewpoint that some developed countries believe that a strengthened IPR regime in India would encourage more technology transfer. In India, the legislation for protection of technology exists in the form of the Patent Act, 1970,[2] which attempts to strike a reasonable balance

[2] This section has drawn upon information in the paper by Dhawan, R. et al. (1988).

between adequate and effective protection of patents, on one hand, and the developmental, technological, and public interest needs on the other. It considers the specific needs and conditions of the country ensuring that protection does not affect public interest or the needs of the critical sectors of the economy nor hinders the build-up of indigenous technological capacity. It is argued that such a regime would favour the diffusion of technology.

1.5 The Dunkel Draft text

The Final Act on the Uruguay Round negotiations of the General Agreement on Tariffs and Trade (GATT), also known as the Dunkel Draft Text (DDT), envisages far reaching changes in the current regime of IPRs, especially that of patents. If implemented, these proposals will have profound impacts on the current Indian system of patents. A look at the proposals is therefore germane to an examination of Indian legislation on patents.

1.5.1 Trade Related Intellectual Property Rights (TRIPS)

The DDT introduces product patents for all inventions, including food, medicine, and chemicals. It extends the protection of IPRs to plant varieties in the form of breeders rights. Further, it provides for the duration of protection to be extended to 20 years, regardless of the place of invention and whether products are imported or produced locally. The Draft provides for extremely strict limits on compulsory licensing of patented products by governments, a device commonly used by governments in rich and poor countries for items such as pharmaceuticals. It also extends exclusive marketing rights for five years after the grant of marketing approval in the interim period when product patent applications are under consideration. The TRIPS Agreement envisages a uniform intellectual property regime. Signatories would no longer retain the right to either frame or pursue their own IPR regime in keeping with their developmental goals.

1.5.2 Trade Related Investment Measures (TRIMS)

The DDT seeks the removal of all TRIMS within a period of five years. The proposals not only seeks to extend national treatment to foreign investors but also aims to deny the impositions of performance obligations imposed on foreign investors in respect of the use of local raw materials, components and equipment, exports, the earning of foreign exchange, technology transfer requirements, etc.

1.5.3 Institutional matters

A council on trade related aspects of intellectual property rights would supervise the operation of the accord, sitting alongside GATT and the envisaged General Agreement on Services under the umbrella of the proposed Multilateral Trade Organization (MTO). The new agreement in regard to trade in services (GATS), attempts to bring within the ambit of the MTO all services such as banking, insurance, shipping, etc. The Dunkel Draft provides for a system of cross retaliation between countries under the disputes settlement mechanism. This allows a country claiming violation of its patent rights

by another country to discriminate against the other in the matter of commodity trade. Further, the Dunkel Draft envisages no special or differential treatment for developing countries.

All these rules would have to be implemented in national legislation by the 102 members of GATT, observing the basic free trade precepts of national treatment and non-discrimination between trading partners.

1.6 Effect of the Dunkel proposals on Indian patent laws

The above examination of the Dunkel proposals reveals that a number of them would have a profound impact on current Indian legislation relating to patents.[3] We briefly examine some of the conflicts between the two.

First, the distinction in the Indian patents regime between product and process patents will have to be removed, since the Dunkel proposals provide only for product patents. Second, the differential terms of patents permitted in India, which vary between 5 and 14 years, will have to be removed and will have to conform to the uniform standard of 20 year operation. Extension of this period could be done further by using process patents. Third, the granting of national treatment to foreign nationals seeking patents becomes compulsory, in contrast with the current regime where such decisions are discretionary. In case of violation of a patent law, the burden of proof will shift from the holder of the patent to the defendant, in contravention of Indian legal principles where, until now, this burden has rested on the holder of the patent.

One of the obligations of the patentee was that the patent was 'workable'; so as to encourage the working of that particular invention within the country. According to the Indian Patents Act (1970): (a) patents are granted to encourage inventions and to secure that the inventions thrive in India on a commercial scale and to the fullest practicable extent without undue delay; and (b) they are not granted merely to enable patentees to enjoy a monopoly for the importation of the patented article. In comparison, import of a patented product would be treated as equivalent to the working of the patent, according to the Dunkel Draft.

Indian patent law not only confers rights of monopoly to the patentee but also ensures public interest by introducing an element of compulsory licensing or license of right clauses. These obligations on the patentee holder are to ensure that the interests of the public are met. However, these obligations are to be removed according to the DDT.

The DDT on TRIPS also completely rejects 'Special and Differential Treatment' presently accorded to developing countries. Although there is provision that the concerns of developing countries *vis-a-vis* meeting public policy objectives will not be neglected, there is only a 5–10 year transitional period which is given to these countries so that the domestic laws may be harmonized.

Being a signatory to this Text would necessarily mean that India has to automatically accept the Convention signed at Paris under the premises of the World Intellectual Property Organization, to

[3] The adoption of a new patents regime will also have significant impacts on prices of commodities and industrial and economic policy in the country, but these are not being considered here.

which it is not a party. In the following sections, the case of cogeneration and lighting technologies will be discussed in the context of technology transfers to India.

2 THE COGENERATION INDUSTRY IN THE CONTEXT OF TECHNOLOGY TRANSFER

2.1 Introduction

India is faced with rapidly growing energy requirements to support its economic development. There is a large potential for reducing greenhouse gas (GHG) emissions associated with the production and consumption of fossil fuels. Issues related to costs, incentives, pricing, and institutional and legal framework necessary to encourage cogeneration are addressed in the paper. Some aspects related to carbon dioxide abatement have also been addressed. However, increasing energy supply capacities to meet the entire projected demand for commercial energy in future will be constrained by limited resource availability. The fact that global interactions on environmental emissions will require the developing countries to give considerable importance to environmental emissions in their national development policies is yet another limitation. The industrial sector presently accounts for over 50% of the total commercial energy consumption in India. Several energy intensive industry categories like sugar, textile, paper, and fertilizer generate their steam requirements internally and purchase electricity from the grid. Opting for cogeneration can enable them to produce both steam and electricity requirements internally, thereby reducing the demand for electricity purchased from the utilities.

Energy intensive industries have enormous scope for cogeneration, whereby they can produce both steam and electricity simultaneously. Electricity generated can be used to meet the internal electric requirements and thus reduce the requirement for utility power. Additionally the surplus, if any, could perhaps be sold to the utilities. Cogeneration thus provides an alternative to the conventional utility power and heat source and reduces the overall emissions from the efficient utilization of fossil fuels.

Despite the fact that cogeneration systems are in use in several industries, there are no efforts to optimize the steam and electricity requirements because of various reasons. No efforts have been made to install cogeneration systems which could generate surplus electricity. Many industries are compelled to continue with non-optimal systems due to company investment criteria, availability of equipment, incremental costs and reliability, and above all, government regulations.

2.2 Concept of cogeneration

Cogeneration is the efficient production of two forms of useful energy from the same fuel resource, using the exhaust energy from one production system as the input for the other. Ordinarily the primary energy form is thermal (steam) and the secondary form is either electrical or mechanical. The electrical or mechanical energy can be used internally to run company equipment and thus reduce the demand for utility power and the surplus electricity, if available, can be sold to the utilities. Such a system can reduce energy input by 10-30% of what is required by separate systems to

same output. Total system efficiency can approach 90%, a significant improvement over the 50–90% efficiency of many industrial boilers and 30–35% efficiency of electrical conversion when separate production is used. As a result, this simultaneous efficient production of two energy forms can significantly reduce total operating costs in many instances even after paying the increased capital costs.

2.3 Benefits of cogeneration

The benefits of cogeneration listed below are derived from improved power cycle efficiency and an associated reduction in fuel consumption as compared to the conventional power plant utilizing fuel solely for generating electric energy.

(i) High efficiency can be achieved by utilizing the same fuel to provide heat and electricity. This would then lead to:
- reduction in fuel consumption, cost, and electric utility bills;
- economic competitive advantages through a maximized return on investment capital; and
- efficient use of capital investment.

(ii) The amount of useful energy produced can be increased through the recovery of otherwise wasted heat. The advantages are listed below.
- The resulting energy conservation would therefore minimize utility electricity demand, utilize available energy for internal process applications and displace other less efficient sources, and recover heat energy from cooling and exhaust systems to add profits to the operation.
- A lesser effect on the environment because of efficient fuel use due to reduced air emissions (sulphur dioxide, nitrogen oxides, particulate) and reduced thermal pollution.
- A reliable source of power and process steam or heat. This is particularly important in regions prone to frequent disruptions in electricity supply.
- On-site electricity generation can eliminate losses (8–10%) in the transmission and distribution systems.
- Cogeneration plants can start operating in two to three years compared to the five to six years for conventional power plants.

2.4 Potential for cogeneration in India

The potential market for cogeneration in industry in the future will be influenced by energy prices in India, the economic situation, restructuring tariff regimes, and/or the introduction of financial aids. National energy policies could also make the electricity supply industry open for competition. There have been very few definitive studies to estimate the potential for cogeneration in India. This section primarily draws upon some of the recent studies and provides the cogeneration potential estimated by them.

The recent initiatives taken by the Government of India in the power sector, and more so in the sugar manufacturing sector, indicate that the state electricity boards (SEBs) are likely to change their tariff structure for the cogenerated power. This can set a precedent for other industries to exploit these

Table 1. Cogeneration potential estimated by the NPC study

Industry	Number of units surveyed	Total power demand (MW)	Cogeneration potential (MW)[a]
Paper and pulp	3	37.5	56
Refineries	4	37.3	40
Rayon	3	17.1	28
Chemicals	9	33.0	47
Fertilizers	9	193.0	250

[a] The cogeneration potential has been determined on a site-by-site basis with regard to suitably tailored power-steam cycles.

changes and generate surplus power to their maximum potential and export to the grid and/or sell to any third party. The major investment in cogeneration is likely to be realized only by independent producers supported by regional electricity distribution companies and the SEBs.

2.4.1 *National Productivity Council study*

The National Productivity Council (NPC) carried out a macro study on the feasibility of cogeneration in the wide cross section of Indian industries in 1979. The study estimated cogeneration potential of 421 MW in 28 of the 150 units surveyed (Table 1). The study further estimated that over 1500 MW of extra power could be generated with marginal investments by applying the cogeneration systems concept. Reviewing the status of energy systems in these units, the study pointed out the following factors responsible for sub-optimal systems from the micro and macro perspectives.

- The general tendency for most units is to generate steam at the maximum process pressure. The demand for low pressure steam is met by and large through pressure reductions.
- Rationalization in the choice of process steam pressures has not been resorted to.
- The power is purchased from the grid for driving process prime movers, refrigeration, etc. The reliability of purchased power is questionable and the industry has suffered in this respect.
- Unutilized boiler capacity for steam generation is high.
- Maximization of heat recovery from process through waste heat recovery devices has not been made use of.

2.4.2 *Inter-ministerial working group on energy conservation*

The study carried out in 1983 estimated that the economic potential for cogeneration in the major industries in India is about 1500 MW.

2.4.3 *USAID study*

A United States Agency for International Development (USAID) sponsored study conducted by Hagler Bailey and Company in 1986–87 focused on the potential for cogeneration in the states of

Table 2. Economic potential for industrial topping cogeneration systems in Gujarat and Maharashtra (1986–96)

Industry	Potential (MW)
Textile	79
Rayon	54
Pulp and paper	57
Refineries	252
Fertilizer	712
Basic chemicals	928
Dyes	76
Food	41
Pharmaceuticals	303
Tyre	13
Soaps	41
Total	2556

Maharashtra and Gujarat. This study estimated a potential of about 2546 MW for industrial cogeneration in these states during the period 1986–96 (Table 2). The study also revealed that the industries with the highest potential were the fertilizer, basic chemicals, refinery and pharmaceutical industries. Topping cycle cogeneration systems accounted for almost the entire potential. One-third of the potential lay in existing plants which could be realized by retrofit or replacement of existing steam generating equipment. The potential from bottoming cycle cogeneration systems has been estimated at about 50 MW, mainly in refineries and in the fertilizer and petrochemical plants.

Presently natural gas is available mainly to the fertilizer and petrochemical industries in the country. The study estimated that if natural gas were made available to all industries, then the potential for cogeneration could be over 3000 MW over the period 1986–96, in the states of Maharashtra and Gujarat alone.

2.4.4 Confederation of Indian Industries study

The cogeneration potential estimated by the Confederation of Indian Industries study in industrial topping and bottoming cycles for Maharashtra state is given in Table 3.

Table 3. Cogeneration potential for topping and bottoming cycles

Systems	Potential (MW)
Industrial topping systems	2150
Industrial bottoming systems	50
Commercial systems—packaged cogeneration unit (studies confined to Bombay city only)	50

Table 4. Cogeneration potential estimated by TERI (1993)

Industry	Potential (MW)
Alumina	59
Caustic soda	394
Cement	78
Cotton textile	506
Iron and steel	362
Man-made fibre	523
Paper	594
Refineries	232
Sugar	5131
Sulphuric acid	74
Total	7953

2.4.5 Cogeneration potential study carried out by TERI

The Tata Energy Research Institute (TERI 1993) has recently carried out a detailed survey of 300 industrial units in the country and estimated cogeneration potential based on the analysis of the data obtained from the questionnaire survey. The cogeneration estimates are based on the internal heat to power ratios which would meet the plant's energy requirements, and on the existing production capacities of the various industry categories. Of the total estimated potential of 7953 MW, the sugar industry is estimated to account for about 65% of the total cogeneration potential. The potential is also significant (500-600 MW) in the textile and paper industries (Table 4). If the power maximization options are to be considered, the cogeneration potential would then be expected to increase significantly.

2.5 Current status and technologies available in India

A cogeneration system is an integration of the various components (energy conversion systems, balance-of-plant systems, heat source, heat pump, etc.) into a total system, which provides the electrical and thermal requirements of a specified industrial process. Cogeneration systems can be broadly categorized into two groups—*topping cycle* and *bottoming cycle*.

In the topping cycle, the primary fuel is used to produce electricity and the thermal energy exhausted is used for process heating. In the bottoming cycle system, the primary fuel is used to produce high temperature thermal energy. The hot exhaust steam is subsequently used to produce electrical energy through the waste heat boilers and turbine generator system. The specific components comprising a cogeneration plant will however depend upon the industry, the energy conversion system, and the strategy picked for sizing the energy conversion system. A brief status report on the technology and availability of some of the components of a cogeneration system in India is given below.

2.5.1 Boilers

The major boiler manufacturers are Bharat Heavy Electricals Limited (BHEL), Thermax, Walchandnagar Industries, Texmaco, ISGEC, IBPL, Lipi, ACC Babcock and others. Most of the

major boiler manufacturers have collaborations with leading boiler manufacturers in the world, e.g., Combustion Engineering, Babcock and Wilcox, John Thompson, etc. Both conventional and fluidized bed combustion (FBC) boilers are being manufactured in India.

Conventional boilers are available as packaged or field erected units in a wide range of capacities and with fuel capability ranging from oil, gas, and coal to rice husk and bagasse. Typical examples of large size boilers supplied are 275 tph for coal fired boilers and 130 tph for oil/gas fired boilers. Packaged oil/gas fired boilers of 80 tph are also in use. The large 275 tph boilers (supplied to electric utilities) supply steam at a pressure of 96 kg/cm^2 at a temperature of 530°C. Boilers with steam pressures up to 110 kg/cm^2 at 465°C have also been supplied for industrial applications. Discussion with major manufacturers indicates that they have the capacity to manufacture higher pressure boilers. FBC boilers that have been manufactured in a wide range of capacities are now being used to fire a variety of fuels like high sulphur-high ash coal, rice husk, rice straw, and even low grade fuels like coal washery rejects.

2.5.2 Steam turbines

There are three manufacturers of steam turbines in India. They are APE Belliss, Triveni Engineering Works, and BHEL. APE Belliss and Triveni manufacture turbines in the lower rating range starting from a few hundred kilowatts to 5–6 MW. BHEL manufactures steam turbines in a wider range of capacities from 1–500 MW (for thermal power plants). These turbines are available with varying functions, i.e., simple back pressure, condensing, extraction-condensing, and multiple extraction turbines.

In the lower range capacity (up to 5 MW), steam turbines are being manufactured to operate at pressures of 30 to 45 kg/cm^2. Most of these turbines are supplied to the sugar industry, and conform to specifications laid down by the National Federation of Co-operative Sugar Factories Ltd. Manufacturers of these turbines claim to have the capability to manufacture turbines rated higher than 65 kg/cm^2 with maximum extraction at about 22 kg/cm^2 for the extraction steam turbines.

BHEL manufactures steam turbines that operate at pressures up to 100 kg/cm^2 and have the capacity to manufacture machines at higher pressures. Turbines with back pressures of over 22 kg/cm^2 have been supplied. BHEL also offers multiple extraction steam turbines with extraction at pressures higher than 22 kg/cm^2. Single-stage back pressure turbines typically operate at an efficiency of 30–40% and multi-stage back pressure turbines in the range of 40–50%. For condensing turbines, typical efficiencies are in the range of 60–70%.

2.5.3 Gas turbines

In India, gas turbines are available from BHEL, Triveni Engineering Works, DLF Energy Systems, and Kirloskar Oil Engines. While BHEL and Triveni supply heavy duty industrial gas turbines (typically in the range of 4.5 to 38 MW), DLF Energy Systems supply aero-derivative gas turbines (1–5 MW range). BHEL is the only manufacturer of gas turbines in the country and these machines are manufactured in collaboration with General Electric. Triveni and DLF Energy Systems supply

Ruston and Allison-GM machines respectively. Typically, gas turbines operate at an efficiency of 22–26% (typical Indian operating conditions) in the lower ratings up to 5 MW.

2.5.4 Diesel engines

There are various manufacturers of diesel engines in the country, manufacturing both high speed and medium speed engines. Low speed and medium speed engines are more suitable for cogeneration application. The major manufacturers in India are Kirloskar Pielstick, Garden Reach, K G Khosla, and Wartsila. The new medium speed engines proposed to be manufactured in the country will be able to use heavy fuel oils of up to 700 centistoke (at 50°C). These engines in the range of 4–6 MW would typically operate at an efficiency of 38–43%. In India, there are only a few installations of diesel engine based cogeneration systems with capacities up to 52 MW.

2.5.5 Waste heat boilers

The main manufacturers of waste heat boilers in the country are BHEL, Thermax, Cethar Vessels, ISGEC, John Thompson, Texmaco, Larsen and Toubro, and Kaveri Engineering. Waste heat boilers of ratings up to 62 tph with single pressure and 105 tph with dual pressures are being manufactured in the country. Among smaller units, used for operation in a cogeneration system, is a 38 tph waste heat boiler used to produce steam at a pressure of 15 kg/cm^2 and 256°C temperature. Installed in a refinery, it uses refinery gas as the heat source. However, most of these waste heat boilers have been supplied to fertilizer and chemical industries and refineries using process gas, natural gas, and residual oil as the fuel. The capability to manufacture fired waste heat boilers also exists in the country and the largest fired waste heat boiler supplied is a dual pressure boiler supplying saturated steam at 39 kg/cm^2 and 10 kg/cm^2.

2.6 Energy and environment

Cogeneration offers the potential for a real reduction in, and a better utilization of, the fuel used for power generation. The actual power to heat ratio can vary widely for cogeneration plants. However, under normal operating regimes, 100 units of fuel input will produce between 20 and 40 units of electricity and 40 to 65 units of high grade heat. This gives overall efficiency and, compared with conventional power production, it represents an energy saving of about 50% for the total process.

Cogeneration offers a significant improvement in both energy efficiency and the reduction of gases damaging to the environment It is therefore an ideal example of a technology that would benefit by promotion. The CO_2 abatement for 2000 AD can be estimated only after taking into consideration the growth in energy intensive industries which have cogeneration potential and the requirement for utility power. The demand projections carried out by the Central Electricity Authority have estimated the power requirement to be around one lakh MW. Projections made by the Planning Commission for coal and other fossil fuels are 126 and 80 000 mt respectively by the end of the eighth Plan. Assuming

the case of coal usage in power generation and industrial process heating and comparing it with coal based cogeneration, the reduction in CO_2 emissions works out to be around 54%. Absolute emission levels can only be worked out after getting details regarding different fuel usage in sectors where cogeneration is applicable.

2.7 Constraints for promoting cogeneration

While the extent of conservation potential through total energy systems has been well appreciated, as also the numerous advantages one would derive from the concept, there are several barriers to cogeneration which restrict the adoption of such systems by the industries. Some of the important barriers are discussed below.

2.7.1 Technology

Cogeneration under the power maximization mode requires high pressure and high temperature system parameters. High pressure boilers, turbines, and accessories are not available in sufficient quantities indigenously. Turbines at high pressure are presently imported. There is also a considerable technological gap between the various advanced configurations and systems available in the developed countries. Table 5 indicates the various technologies available. There is a need to identify areas of R & D in the various cogeneration technologies required in the country.

2.7.2 Financial constraints

One of the major problems for a firm interested in cogeneration is the relative capital intensity of a cogeneration system. The capital cost of a cogeneration system may range from $500–1000 per kilowatt of installed capacity for oil and gas systems to $1000–1500 for coal, wood, or biomass systems. In times of high interest rates and credit restrictions, such as those we have recently experienced, this capital intensity makes the financing of such systems a major consideration in their successful development. Where the firm's overall economic picture limits its ability to use the tax benefits associated with such projects, third-party ownership is the answer to this problem in India.

Hence, the industries find it difficult to raise resources for the incremental cost of setting up a cogeneration system with the objective to sell surplus power to the utilities. The tax and duty structure on the capital equipment used for the cogeneration facility is not as attractive as in the case of other non-conventional energy sources. Liberal credit facilities such as concessional interest rates and larger repayment periods should be provided to the industries to encourage cogeneration.

2.7.3 Legislative constraints

Presently, there is no legal framework for the purchase of surplus cogenerated power. Unlike the US where, under the PURPA (Public Utility Regulations Policies Act), it is mandatory for public utilities to buy the energy generated by the cogenerator at the avoided cost, there is no such requirement in India. Avoided cost is the incremental cost to the electric utility that the utility will either generate

itself or purchase elsewhere if it did not purchase from the cogenerator. Very few SEBs have encouraged cogeneration. In fact, the self-generated sales tax imposed by the state tax authorities has acted as a disincentive for the industries to opt for cogeneration. Except for two or three SEBs, other utilities do not have any arrangement for wheeling and banking of cogenerated power. It is important to have long-term purchase contracts between the SEBs and cogenerators for purchase of surplus power to encourage industries to opt for cogeneration under the power maximization mode.

2.7.4 Pricing policy and cost considerations of cogeneration

One of the most crucial factors, in promoting cogeneration, relates to the agreement on the tariff policy. There is no clear pricing policy for purchase of power. Utilities, while carrying out their long-term planning exercise, must consider the cogeneration option as a source of firm power supply in relation to conventional power generation options. The tariff for cogenerated power should therefore be set at the avoided cost for new capacity added for meeting the base load demand.

Except for two or three SEBs, the utilities in India do not have any formal policy for purchase of cogenerated power. Ideally, the utilities must pay the marginal cost or the avoided cost of their own power generation or purchase from any source other than the cogenerator. Utilities however, under the principles of grid discipline, consider the short-run marginal costs (fuel and operating costs). This makes the cogeneration option unviable and therefore deters investments by the industries. However, under the power maximization option, incremental capacity is added by the industry with the sole objective of supplying to the grid and the cogenerator must be paid both capacity and the variable costs.

2.7.5 Technical barriers and problems of parallel operations

The quality of electric power has always been a major problem with the utilities in India. High voltage fluctuations, frequency variations, and frequent power failures are factors, that need to be taken care of, which add to the cost of the cogeneration plant. The cogenerator may have a slightly different set of concerns, like safety, interconnection costs, production of the cogeneration system, power factor costs, and impacts on production.

Utility system reliability is also affected by the location of the cogeneration interconnection on the utility system. If the interconnection is at a transmission level, then interruptions of service have a greater potential impact than those at a distribution level. The utility may require even more stringent protection requirements from the cogenerators connected to the transmission system to protect other customers who exist 'downstream'.

Another consideration is the generator size compared to the plant load and the load on the utility line. This will usually result in more stringent protective requirements since the utility and the cogenerator will again seek to protect utility and customer equipment from service disruptions. Harmonic currents pose yet another problem that may occur at frequencies other than the desired 50 Hz of the power signal. When transmitted along power transmission and distribution lines, these harmonics distort the power signal.

Both the cogenerator and the utility need to protect their respective personnel and facilities from injury and damage that could be caused by generator misoperation. This protection often utilizes automatic equipment to detect and isolate the faulty sections of a circuit so that the remainder of the network can continue to deliver power without interruption.

Table 5. Status of cogeneration technologies available abroad

Technology type	State-of-the-art	Number of design options	Fuel
Steam turbine	Current	10	Petroleum boiler fuel
Steam turbine	Current	10	Coal
Diesel (high speed)	Current	2	Petroleum distillate
Diesel (low speed)	Current	1	Petroleum boiler fuel
Gas turbine (combined)	Current	4	Petroleum distillate
Steam turbine	Current	1	Petroleum distillate
Steam turbine	Advanced	10	Coal derived boiler fuel
Diesel (high speed)	Advanced	10	Coal (AFB)
Diesel (low speed)	Advanced	1	Coal derived
Diesel (low speed)	Advanced	2	Coal derived distillate
Gas turbine	Advanced	1	Coal derived boiler fuel
Gas turbine	Advanced	5	Coal (pulverized)
Gas turbine	Advanced	5	Petroleum boiler fuel
Gas turbine	Advanced	2	Coal derived boiler fuel
Gas turbine (indirect)	Advanced	4	Coal (gasifier)
Gas turbine (closed cycle)	Advanced	3	Coal (PFB)[a]
Gas turbine (closed cycle)	Advanced	5	Coal (AFB)[b]
Steam injected gas turbine	Advanced	5	Coal derived boiler fuel
Steam injected gas turbine	Advanced	2	Petroleum boiler fuel
Steam injected gas turbine	Advanced	2	Coal derived boiler fuel
Steam injected gas turbine (indirect)	Advanced	2	Coal (PFB)
Combined cycle	Advanced	2	Coal (AFB)
Combined cycle	Advanced	3	Petroleum derived
Combined cycle	Advanced	3	Coal derived
Combined cycle	Advanced	1	Coal (PFB)
Combined cycle (indirect)	Advanced	2	Coal (AFB)
Fuel cell (low temperature)	Advanced	2	Petroleum distillate
Fuel cell (low temperature)	Advanced	2	Coal (derived distillate)
Fuel cell (high temperature)	Advanced	2	Petroleum distillate
Fuel cell (high temperature)	Advanced	4	Coal (derived distillate)
Fuel cell (high temperature)	Advanced	1	Coal (gasifier)
Sterling	Advanced	2	Coal (derived distillate)
Sterling	Advanced	2	Coal (gasifier)
Thermionics	Advanced	2	Coal derived boiler fuel
Thermionics (compound cycle)	Advanced	3	Coal derived boiler fuel
Steam turbine bottoming	Current	10	By-product heat
Organic rankine bottoming	Advanced	3	By-product heat

[a] Pressurized fluidized bed; [b] Atmospheric fluidized bed.

When cogenerators are present, several areas of utility planning may be affected because of the dispersed locations of the cogenerators. These impacts may show up in the following areas—voltage regulation, load restoration after interruptions, and sufficient circuit capacity. Utilities will also need to account for deviations from their expected load surveys and load factors caused by dispersed generation. These form the foundation of utility planning. Both of these are affected by dispersed generation, which is usually not planned for, and displaces some electrical demand as well.

2.7.6 The two-part tariff system introduced by the Ministry of Power

The Ministry of Power, under their policy decision to encourage private sector participation in power generation, has introduced a two-part tariff system which would guarantee returns to the private investors. The first part of the tariff ensures recovery of fixed costs (including returns) based on the performance at normative parameters. The second part ensures meeting of variable expenses based on units of electricity actually supplied. Incentives will be provided for the achievement of efficiency levels higher than the normative parameters. Once the rate for the sale of power is fixed, no limits of any sort will be put on actual profits earned by a generating company. The system also provides for the signing of a Contractual Agreement, laying down rates for the bulk sale of power by a generating company to an SEB for a specified period.

2.7.7 Conclusions

Most of the possible technologies for cogeneration are available in India. However, continuing technological self-sufficiency will require technology transfer of certain advanced cogeneration systems as indicated in the Table 5. There is also a need to increase R & D activities in certain specified areas relevant for India. A need for information dissemination among the industrial and the commercial sectors is also recognized.

3 Specific technology study on energy efficient lighting technologies

3.1 Introduction

Lighting systems rank among the first few end uses that are connected to an expanding electricity system. Particularly, in the socio-technical context of a developing country like India, lighting is synonymous with electricity and stands out as the sole emblem of electrification. This has resulted in a tremendous increase in the number of lighting systems and their emergence as one of the more important end uses of electricity.

However, the technology used is old and energy inefficient implying that lighting also contributes significantly to CO_2 emissions. Several researchers have attempted to quantify the amounts of energy consumed in lighting systems and analysed the potential to conserve energy through efficiency improvements in lighting systems.

In India, four different types of lighting systems are widely used—incandescent, fluorescent, mercury vapour, and sodium vapour. Table 6 shows that over 80% of the incandescent energy use is

Table 6. Lighting electricity use by sector and lamp type (TWH)

Sector	Type of lighting system			
	Incandescent	Fluorescent	Mercury	Sodium
Domestic	7 4	0.3	0.0	0.0
Commercial and miscellaneous	1.2	6.2	0.1	0 1
Industrial	0.3	6.5	1.2	0.8
Public lighting	0.2	0.9	0.2	0.3
Total	9.1	13.9	1.5	1.2

Source. Data file of the Tata Energy Research Institute (1991)

in the domestic sector, over 90% of fluorescent energy use in the industrial, commercial, and miscellaneous sectors, and over 60% of mercury and sodium vapour lamp energy use is in the industrial sector. However, Indian electric utilities do not have precise data on the contribution of electric lighting to the total utility load. This is because electric lighting is required by domestic, commercial, and industrial consumers and no separate metering arrangements exist to determine the contribution of electric lighting to the total load for each sector. Hence all the available data is based on sample surveys or on macro level assumptions on the share of lighting in the total connected load or on the utilization pattern of lighting equipment.

Gadgil and Jannuzzi (1991) estimated the share of electric lighting to be 17.4% of India's annual energy consumption. If the electric lighting requirements during system peak were to be fully met, they would constitute 30–35% of this unrestricted demand.

Data based on a sample survey of 400 consumers in Delhi indicated that the percentage share of lighting in the total connected load was about 15–20%. In villages, the share of energy use in lighting is much higher (70%), due to the restricted appliance ownership pattern of rural consumers. The break up of this connected load in four electrical districts where the survey was conducted is shown in Table 7. Similarly a survey of domestic and commercial consumers conducted in South Bombay showed that domestic lighting contributes 18.7% of the system load during peak time.

Table 7. Percentage share of lighting in the connected load

District	Fluorescents	Incandescents
1	40	60
2	26	74
3	24	76
4	23	77

Source. Data file of the Tata Energy Research Institute (1991)

Table 8. Number of light points by sector (million)

Sector	Incandescent	Fluorescent	Mercury	Sodium	Total
Domestic	140.69	5.63	0.00	0.00	146.32
Commercial	6.28	25.13	0.00	0.00	31.41
Industrial	1.18	19.57	1.89	0.94	23.58
Public Lighting	2.20	7.11	0.44	0.51	10.26
Others	1.58	11.06	0.55	0.24	13.43
Total	151.93	68.50	2.88	1.69	225.00

Source. Data file of the Tata Energy Research Institute (1991)

The share of lighting contribution to peak electricity demand is expected to increase in future and this is mainly attributable to the listed below factors:

(i) The population in the rural areas accounts for about 75% of the total population of India. Inspite of large scale rural electrification programmes, only about 25% of the households in electrified areas actually have electricity in their homes. As electricity becomes more accessible to rural consumers, the lighting demand is bound to increase further.

(ii) The shares of both domestic and commercial electricity consumption have been steadily increasing (Table 8). Lighting and space conditioning loads are primarily responsible for this trend which is also likely to continue in the future.

3.1.1 Savings potential

As mentioned earlier, the increasing migration of population from rural to urban areas, shift from non-commercial to commercial sources of fuel, and large scale rural electrification programmes have increased the share of domestic and commercial sectors in total energy consumption from 17.3% in 1980–81 to 21.64% at the end of 1988–89. Lighting systems have become an integral part of domestic and commercial units. Energy efficiency in lighting is of significant importance due to a very high peak coincidence rate. Majority of the lighting equipment in domestic and commercial sectors is used in the evening hours which is also the peak demand period for most systems in India.

There are several options for improving the energy efficiency of lighting systems in the domestic sector. These are:

(i) replacement of incandescent lamps by conventional tubular fluorescent lamps fixtures;
(ii) replacement of incandescent lamps with compact fluorescent lamps;
(iii) use of this line fluorescent lamps in place of conventional fluorescent lamps; and
(iv) use of electronic ballasts for fluorescent lamp lighting systems.

There are many more technological options for the improvement of end use efficiency in lighting but we feel that only these could make a significant impact on the Indian power scene. The stock of

lamps in India in 1991 was about 225 million of which incandescents accounted for about 152 million and fluorescents for 68.5 million. The details of the number of light points have been given in Table 3.

Incandescent lamps have a lifetime of about 1000 hours as compared to the 4000 hour lifetime of conventional tubular fluorescent lamps. CFLs last for about 8000 hours. Longer life and a higher luminous efficacy provide a distinct advantage to fluorescent lighting systems over incandescent lamps.

It is expected that the installed lamp stock in India would be about 1 billion in the year 2000. This would consist of approximately 600 million incandescents and 400 million fluorescents. A study carried out by TERI, estimates that replacing 50% of the incandescents by fluorescents would result in annual energy savings of 12.5 TWh at a cost of US$ 0.44 billion (assuming 1000—of hours of use). Accounting for T & D losses and generation mix, this amounts to saving 11.36 TWh of coal based generation annually. This implies a 3.72 mt CO_2 (in carbon content) reduction annually. However, if incandescent lamps were replaced by CFLs, 14.15 TWh of coal based generation could be avoided. This would lead to a 4.63 mtoe reduction in CO_2 emissions.

3.2 Indian lighting industry

While the technology for manufacturing fluorescent lamps and electronic ballasts is available in India, technology for manufacture of compact fluorescents and other new lighting accessories is still not available indigenously. An attempt was made by the Department of Scientific and Industrial Research to evaluate the state of the Indian lighting industry. The report recommended introduction of new energy saving lamps, support and upgradation of small scale units, R & D thrust in basic lamp making processes, and establishment of an All India Institute of Lighting Technology.

The conclusions which emerged from the report are summarized below.

(i) The industry has been generally slow in product innovation and machinery renewal.

(ii) The industry is characterized by poor productivity, high production costs, and low material efficiencies. It was felt that the quality of materials and components need to be improved.

(iii) To improve the lighting industry to world standards, provision of free technology and reduced import duty on sophisticated equipment for manufacturing energy saving lamps and their accessories would be helpful.

General lighting service (GLS) lamps manufactured in India are in the range of 15–2000 W and are used for general purpose lighting in domestic and commercial units. The luminous efficacy of the lamps range from 8 to 15 lm/W. About 75% of the GLS lamps, which are for use in domestic (and certain commercial) applications, is manufactured by 20 large and medium scale companies in India. Production levels rose from 12 million pieces in 1940 to about 260 million pieces in 1990.

Fluorescent lamps in India produce between 60–80 lm/W and can be designed either for high efficacy or to have good colour rendering properties. Fluorescent lamps were initially manufactured

in Calcutta. At present, there are about 20 large and medium scale units in the organized sector producing about 48 million pieces annually. These units have been operating at low utilization factors and there is considerable scope for increasing production without additions in capacity.

3.2.1 Technology acquisition

As regards CFLs, the technology for manufacturing them is not available in India at present although several companies are planning to manufacture these lamps in India in the near future. In the meantime, CFLs are being imported into India in small quantities. The technology for these projects would be made available by Philips (The Netherlands), Osram (Germany), General Electric (USA), and Phoenix Electric (Japan) to their counterparts in India—Philips India, Surya Roshni, Apar Ltd, and Halonix Ltd, respectively. The acquisition of technology has not been a problem, as all these Indian companies had pre-existing tie-ups for manufacture of other type of lamps. Discussions with the manufacturers revealed that there were no hesitation on the part of collaborators to provide the latest technology. However, the manufacturers felt that the prevailing import duties on equipment should be reduced from the present figure of 110% plus countervailed tax as an incentive to manufacture compact fluorescent lamps in India.

3.2.2 Technology absorption

Indian consumers seek to minimize the initial cost of a piece of equipment and tend not to pay much attention to operating costs. Therefore, there is a general consumer reluctance to invest in efficiency. CFLs, being approximately 10 times more expensive than conventional sources of light, do not find consumer acceptance. At present, consumers in India are looking at CFLs more as a fancy lighting system than as an energy efficient source of lighting. Discussions with manufacturers also indicated that, at present, it would not be economically cost-effective to manufacture these lamps in India as the market is yet to develop. Some of the manufacturers are planning to go in for CFL manufacturing plants in export processing zones which offer reduced customs duties for import of equipment in return for a firm export commitment. These export oriented manufacturing zones also allow units to sell a small percentage of their production in the domestic market. At present, there is a shortage of CFLs in the international market which the Indian manufacturers could possibly exploit. As mentioned earlier, the manufacturers are trying to first build the market by slowly exposing the consumers to this technology and making small quantities of CFLs available imported from their respective collaborators. They feel that innovative financing schemes are required to increase the demand of these lamps in India. The manufacturers are looking at large campuses belonging to autonomous bodies and public sector companies to test innovative financing strategies. For achieving this end, some of the manufacturers are also planning to tie up with leasing firms. Another measure to increase penetration of CFLs in India would be through introduction of such schemes by government funding agencies/financial institutions. The Industrial Development Bank of India has implemented such a

scheme for industrial consumers. Under this scheme, industries get 90% of the total amount required for changing over from high pressure mercury vapour lamps to high pressure sodium vapour lamps. The remaining amount is recovered through part payments over a period of five years. There is a strong need to demonstrate CFL effectiveness through model projects. Government support could prove to be significant in supporting such projects to increase the penetration of CFLs in India.

3.2.3 Technology adaptation

There are several labs in India which test lighting equipment and issue certificates of performance levels. However, at present the Bureau of Indian Standards (BIS) does not have any standards of performance for CFLs. The basic infrastructure for lamp testing does exist in all the labs belonging to the BIS. Apart from labs of the BIS, the national test houses and some of the regional test centres also have facilities for testing lamps. At a later stage, these facilities could be upgraded to test CFLs. Among the research institutes in India, the Central Power Research Institute at Bangalore has carried out fundamental research on CFLs. This institute has also conducted a study on the performance of CFLs. This study addresses technical aspects pertaining to the performance of CFLs under Indian conditions. The National Physical Laboratory, a government funded research lab, also has infrastructural capabilities for testing and research purposes. However, such facilities are overburdened by requests from a large number of interested clients. There is an urgent need to increase the number of test centres in view of the increasing demand.

4 Conclusion

It is anticipated that the emissions of CO_2 from a developing country like India is likely to increase rapidly, given our increasing energy needs. Although there are requirements for stabilizing CO_2 emissions on the part of developed countries, efforts along similar lines in the case of developing countries would be contingent on the former's assistance in enabling technology transfer.

This chapter examines potential CO_2 abatements through the use of cogeneration and efficient lighting options. The need for adopting such abatement measures is underlined by the fact that estimates place the consumption of current commercial energy consumption by the industrial sector at more than 50 percent. The second option that of efficient lighting technologies suggests itself due to its role in reducing end-use energy consumption in the Indian power sector (estimated at approximately 18 percent).

The section on cogeneration clearly shows its potential for adoption particularly in some of the energy intensive industries leading to the efficient use of fossil fuels apart from the simultaneous generation of power and steam. Some of the identified constraints for its non adoption relate to requirements of R & D for cogeneration technologies, financial constraints resulting from tax and duty structure on capital equipment among other aspects.

Although the paper indicates that there have been significant changes in the policy environment aimed at overcoming barriers prevalent in technology transfer, the study points to the need for further incentives, restructuring of tariff regimes, financial assistance among other measures. For instance a changeover to efficient technologies would be facilitated by removal of duties on lighting system components, for example tri-band phosphor fluorescent powder hitherto not manufactured in India. Government intervention could allow for the development of innovative financing schemes for promotion of efficient lighting technologies.

REFERENCES

1 Gadgil A, Jannuzzi G. 1991. Conservation potential of compact fluorescent lamps in India and Brazil. *Energy Policy* 19(5): June 1991.
2 Sridharan E. 1991. Liberalisation, self-reliance and technology policy in India in the eighties: a shift in the terms of discourse. Delhi: Centre for Policy Research.
3 TERI. 1991. Data file of the Tata Energy Research Institute. New Delhi: Tata Energy Research Institute.

BIBLIOGRAPHY

1 Bell M. 1990. Continuing industrialization, climate change and international technology transfer. Report prepared in collaboration with the Resource Policy Group, Oslo, Norway. Sussex: Science Policy Research Unit, University of Sussex.
2 Bhatia K. 1992. Personal communication. New Delhi: SURYA Ltd.
3 CII. 1988. A status paper on cogeneration. New Delhi: Task force on Energy, Confederation of Indian Industries.
4 CPRI. 1991. Evaluation of energy efficient lamps: compact fluorescent lamps. TR 230. Bangalore: Central Power Research Institute.
5 DSIR. 1988. Report on technology evaluation in electric lamp industry. New Delhi: Department of Scientific and Industrial Research, Government of India.
6 GOI. 1992. General Review. *Economic Survey 1991/92* (Part I). New Delhi: Economic Division, Ministry of Finance, Government of India.
7 GOI. 1992. Sectoral developments. *Economic Survey 1991/92* (Part I). New Delhi: Economic Division, Ministry of Finance, Government of India.
8 Kirpal V. 1992. Personal communication. New Delhi: APAR Ltd.
9 Menon K S V. 1991. *Technology Transfer: Concept, Modalities and Case studies*. New Delhi: Goldline Publishers.
10 Nadel S, Kothari V, Gopinath S. 1991. Opportunities for improving end-use efficiency in India. Report prepared for the World Bank. Washington, DC: United States Agency for International Development.
11 Shome G. 1992. Personal communication. New Delhi: PHOENIX Electricals Ltd.
12 Subha Rao S, Sudhakar A. 1985. Some aspects of integrated energy generation and utilization. *Steam and Fuel Users Journals*: January-March.
13 TERI. 1987. Strategies for electric load levelling in India: Phase I. Report submitted to the Advisory Board on Energy, Government of India.
14 TERI. 1991. Technical, policy and economic assessment on energy conservation from efficient electric lighting. Report submitted to the Department of Power, Government of India.
15 TERI. 1992. Energy conservation measures in the domestic sector. Report submitted to the Energy Management Centre, Government of India.

Technology transfer of cogeneration systems and corresponding CO_2 emissions reduction opportunities in Indonesia

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Introduction

An investigation on the status and development of the functioning of cogeneration systems in Indonesia, an evaluation of the opportunities for its wider application, and an analysis of the corresponding potential for CO_2 reduction has been carried out in this paper. It is mainly concerned with (i) opportunities that are open for the wider functioning of cogeneration systems in Indonesia, (ii) the past and present role of international transfer of technology in influencing a wider application of cogeneration system, (iii) the pre-conditions for promoting a better environment for technology transfer, and (iv) what the potential capacity of cogeneration in Indonesia is and what would be the amount of CO_2 emissions that could be avoided if the potential is fully exploited. Having analysed the technology transfer issues pertinent to the wider functioning of cogeneration systems, the need and opportunities for technology transfer of cogeneration systems in selected applications are identified, and the potentials of beneficially implementing the technology in those selected applications are estimated, in terms of energy efficiency improvements.

In the energy development of the country, although the electricity supply capacity has been growing at very high rates, yet there is unmet demand. The current estimate is that for the coming years, the average demand growth rate for the period of 1994–1998 will be around 17% per annum, declining to 12% during 1999-2003, and in the following five year development plan (2003–2008) may further decline to an average of eight per cent per annum. Even though there is a declining trend in the projected demand growth rates, the figures are very high. Most of the power demand is concentrated in the island of Java.

Since both oil and natural gas play determining roles as sources of foreign exchange revenue, and also because of declining reserves, the availability of oil and natural gas will be limited. The power sector is therefore anticipated to be dominated by coal based generation plants. However, such a high share of coal utilization is presently considered to be environmentally undesirable, unless less polluting coal technology and mitigative techniques are utilized. This will require higher investment costs, while capital availability is highly constrained.

Conservation measures in the power sector have to be pursued, and there is a considerable potential for that. The present total loss in the transmission and distribution is still relatively high, i.e., within the range of 23–26%. Furthermore, demand-side management (DSM) has not been practised. Efficiency improvement in the power sector is also desired, in terms of fuel conservation and from the environmental point of view.

As one of the many means of achieving improved efficiency, this study has focused on the potentials of wider application of cogeneration technology. While the technology is not entirely unknown in the country, it is observed that there is a considerable degree of lack of familiarity and appreciation.

2 Overview of the Indonesian energy setting

2.1 General overview

Oil dominates the supply and consumption of energy in Indonesia. Other major commercial energy producers and consumers, in decreasing order of relative shares, are natural gas, hydropower, coal, and geothermal. Biomass, as a traditional form of energy, has a very high share in the total energy supply, currently estimated as 40%. It is mainly used in the rural and urban peripheral residential sector.

The share of coal in domestic energy supply presently is still very low. However, coal utilization has been accelerating for the past five years, and the level of production is increasing rapidly too. This trend is a consequence of the government policy on energy during the Fourth Five Year Development Plan (Repelita IV—1984/85–1988/89), where it was stipulated that, to maximize foreign exchange revenue from oil export domestic uses of oil should be replaced by non-exportable energy resources, or other resources, that are less attractive in the international market.

Electricity generation as a component of energy supply has also developed at a rapid rate, catering to the growing needs of the industry, urban households, and rural electrification programmes. Considerable opportunity for improvement with respect to losses can be found in the power sector. The margin between electricity production by the State Electricity Company (PLN) and its consumption is about 23–25% of the generated electricity. An overview of energy resources in Indonesia is given in Table 1.

During the last decade, the industrial sector consumed the highest share of commercial energy, followed by the transportation sector. The most rapidly increasing consumption is also found in these two sectors. The developments in energy demand are described below.

- During the periods prior to launching of the series of Repelita, energy demand growth rate was 7.4% per annum.
- The average annual growth in energy consumption in each Repelita (between 6.4 and 12.7%) has always been higher than the average annual economic growth (4–7%).

Table 1. Energy resources of Indonesia

Resources	Units
Oil (tonnes)	6.78×10^9
Natural gas (m^3)	6.04×10^{12}
Coal (tonnes)	28.3×10^9
Hydro (MW)	75 000
Geothermal (MW)	16 000
Uranium	Indicated
Peat (tonnes)	200×10^9
Wind	Prospective
Biomass	
Forest area, agro, silvicultural waste (m^2)	1.085×10^6
Tidal, wave, and ocean-thermal	Identified

The high rate of growth of the commercial energy consumption is the result of several factors. The major factors are the investment expansion in energy intensive industries, the rapid growth rate in electric power generation, and the population growth.

2.2 Energy conservation programme

The Indonesian government has planned a national programme on energy conservation. It consists of four parts, namely, public education and campaign; technical information services; laws and regulations; and research, development, and demonstration.

The first phase of the programme was launched in early 1980. Towards the end of 1983, the second phase of the programme was started by implementing an in-depth energy audit and analysis in selected energy intensive industries, power generation and distribution, transportation, and commercial sectors. The results were expected to be used to identify potential energy savings, needs, and problems to establish the basis for the following phases.

The industrial sector has been the main target as it is a major energy consumer. Energy savings were found to be economically beneficial, although with the prevailing subsidized energy prices such measures are not appealing, particularly, to the individual enterprises. The government has established a permanent national committee on energy conservation with a comprehensive task that includes the formulation of laws and regulations, guidelines, and campaign. Recently, a presidential decree on energy conservation has been issued, and a master plan for national campaign on energy conservation is being formulated.

2.3 Environmental issues related to energy

An overview of the identified and observed environmental issues and effects related to energy development in Indonesia is presented in Table 2. Measures for environmental protection has been undertaken with the issue of the Environmental Law in 1982, in which it is stipulated that the Environment Impact Assessment (EIA) is mandatory for all projects, prior to their approval for implementation.

Table 2. Environmental issues and effects related to energy development and utilization

Area	Environmental problems	Environmental issues	Affected areas
Air	Air pollution Particulates (dust) Carbon monoxide Carbon dioxide Hydrocarbons	Urban air pollution due to transportation and dust	Major cities in Java, (Jakarta, Bandung, Surbaya, Semarang) Medan
	Lead	Human intake of lead	Major cities in Java (Jakarta, Bandung)
	Nitrogen oxides	Urban pollution	Bandung
	H_2S	Geothermal development	Dieng, Kamojang, Mount Salak
	Acid precipitation	Urban and power plants	Mura, Karnag, Jakarta
Water	Oil spills	Marine pollution	Offshore areas, tankers
	Brines/organics	Coastal pollution	Oil refineries in Cilacap, Dumai, East Kalimantan,
	Acid mine drainage	Coal mines	Ombilin, Bukit Asam, East and South Kalimantan
	Heat discharge	Thermal pollution	Power plant effluent in Jakarta Bay
		Hydrological balance	West, Central, and East Java
	Loss of habitat	Coastal pollution	Bontang Bay, Jakarta Gulf
Land	Land disturbance Aesthetic blight Loss of habitat Subsidence	Land use transformation, deforestation, environmental hazards	Coal mine areas, power plants hydropower, onshore oil
	Leachate Storage/disposal waste	Solid waste	Coal mine areas, energy processing and conversion
Social	Population	Resettlements	Hydropower development

2.4 Energy policy, planning, and institutional framework

2.4.1 Energy policy

The development in the energy system has taken place within an energy policy the implementation of which has the following basic features.

- Pricing of energy is regulated by the government.
- Declining share of domestic petroleum consumption is pursued, so that export volume of oil can be maintained or increased as targeted.

- Energy conservation is promoted, but there have not been any effective policy measures to support the policy objectives.
- Policies on natural gas utilization and pricing are not specifically and explicitly formulated in a comprehensive way.

Concurrent with the objectives and priorities of the national development, since 1988 the policy on energy development has been revised, and has the following orientation.

- Prudent and efficient management of energy development and utilization, with due consideration to the growing energy need, opportunity for export, and the long-term sustainability of energy resources; and efforts for diversification through enhancement in exploration, utilization, and wider social acceptance of alternative energies are pursued.
- Conservation of energy, particularly with respect to depletable oil derived energies, is to be pursued through, among others—appropriate pricing policy, the use of energy efficient systems, and a campaign for a life-style that can prevent wasteful use of energy.
- Development of alternative energy sources is to be pursued with due consideration to the safety and sustainability of natural resources and the environment.
- Enhancement of the human resource capability and capacity in energy sector.
- The national capability and capacity in science and technology on the supply and utilization of energy have to be pursued through R & D, education, and training.
- Development of the power sector to support the economic activities, from the point of view of the improvement of the welfare of the people and the rural and urban communities.
- Strengthening national resilience, to cope with future development needs through proper management in the supply and use of energy.

To achieve the policy objectives and the specific targets in shifting the energy mix towards the lower share of oil, a set of policy programmes is defined, through which the following are pursued: increased identification and estimation of Indonesian energy resources and reserves; increased usage of different fuel types and power generation technologies; and increased efficiency in energy conversion processes.

The priority ranking for energy development in the near future is as follows—hydro and geothermal, coal and natural gas, and new and renewable energy. The general policy on energy also includes, as its component, considerations concerning the creation of better climate for energy developments and environmental management aspects, particularly with respect to the energy industry, investment, and energy price, where the shift towards zero subsidy is to be gradually achieved.

Regarding environmental issues, the general policy on energy stipulates that the sustainability of environmental bearing capacity and functions must be maintained by way of diversifying the supply of energy, enhancing conservation measures, developing local resource-based energy supply systems, minimizing disturbances to environmental functions and bearing capacity, alleviating environmental

pollution around abandoned energy mining and development sites, and preventing negative social effects in undertaking energy development projects

2.4.2 Energy planning

Energy planning in Indonesia is undertaken within the realm of the national development planning. The national plan on energy development is covered under the development plan on mining and energy. The major responsibility for producing the plan formulation in the energy sector, rests with the Ministry of Mines and Energy (MOME). Inputs for the planning formulations are taken from the major state energy enterprises, namely oil and gas (PERTAMINA), electricity (PLN), the state coal enterprise, and gas utility (PGN), and from other ministries. Other major agencies that are supposed to contribute important inputs are the Agency for Assessment and Application of Technology (BPPT) and the National Atomic Energy Agency (BATAN).

The formulated plan would then go to the National Planning Agency (BAPPENAS), where it is synthesized and integrated to become a component of the Five Year National Development Plan (Repelita). With reference to the Repelita, detailed yearly planning, mainly in relation to public sector activities and yearly government budget planning preparation, is carried out. Then they are translated into specific programmes and projects. The planning for implementing the programmes and projects still needs considerable improvements. In the energy planning, lack of co-ordinatory functions to cope with incoming initiatives and to anticipate situational changes, and appropriate and timely incorporation of these changes to on-going plans as well as for long term considerations, are observed.

2.4.3 Institutional framework

At the national level, the task of formulating policy on energy is assigned to a National Energy Coordinating Board (BAKOREN), a ministerial level body of 14 members, chaired by the Minister of Mines and Energy. In undertaking its tasks, the Board is supported by a national committee, designated as the Technical Committee on Energy Resources (PTE). The Committee prepares the draft for formulating a policy on energy. The overall scope of work of the committee is:

- review and study of current and future energy issues;
- review and analysis of information, pertinent to energy policy formulation and planning;
- monitoring of all follow-up programmes and activities of government decisions on energy; and
- submitting its appraisal to BAKOREN.

Being the key government agency on energy affairs, MOME has a broad range of responsibilities that include energy planning, resources delineation and development, oil and gas exploration, production and marketing, and development of coal, geothermal, and power sectors. Within the government establishments, energy R & D activities, in support of policy formulation and planning, are carried out by several government R & D agencies. Contributions from independent and university research establishments have always been solicited.

If one looks at the structural side of the Indonesian energy policy and planning institutional framework, it is clear that the necessary government institutional elements are in place. What is most lacking is the establishment of a strong co-ordinatory support system and the operation of an effective and productive technical support system that deals with data maintenance, in-depth analysis, and preparatory ground work in producing policy and planning formulations. There are no specially assigned resources on a full-time allocation basis for all these functions.

These weaknesses result in the bias towards the supply-side in planning considerations and, therefore, inadequate attention is given to DSM. A balance in the supply and demand considerations, which should also take environmental factors into account, would require considerably higher capacity in policy analysis and planning exercises.

2.5 Additional remarks

An area that requires considerable attention in energy development is the power sector. A great deal of effort is required, both in terms of capacity expansion and in terms of efficiency improvements. The rate of growth of the sector has been very high, and is projected to have similar high growth rates for the coming two decades.

On the supply side, the choice of reliable and efficient systems and environmentally less damaging technology, in addition to economic considerations, is extremely important in implementing the power sector expansion programme. There is also considerable room for reduction of transmission and distribution losses. On the demand side, there is even more room for better management.

Considering that Indonesia, being a developing country, has yet to cope with problems related to a set of development imperatives, the available resources that can be allocated for technology development is highly constrained. In the efforts for improving the performance of the systems in the power sector, acquisition of the required technologies by way of technology transfer from external sources would be a better route, if not the best available option.

3 Major issues in technology transfer processes

Prior to analysing the problem of technology transfer of the systems, the general environmental pertinent to the implementation of technology transfer process will be elaborated. This section begins with a brief evaluation on relevant issues in terms of a set of identified major parameters affecting technology transfer processes in Indonesia. Subsequently, a discussion that focuses on technology transfer in the power sector, where cogeneration has a part will be given.

3.1 An evaluation of the main parameters affecting technology transfer processes

Of the many parameters affecting technology transfer, economic development, and the business environment, where the development is taking place, the technology institutional set-up, and the level of capability are to be considered.

3.1.1 The general environment for technology transfer

Salient features of the Indonesian economic development

In the 1970s, Indonesia experienced relatively high economic growth of around 7.8% per annum mainly due to the high oil prices in the international market. The drop in oil prices in the 1980s has affected the economy negatively—the economy grew at around 5.7% on an average. In reaction to the declining oil revenues in 1983, a series of economic reforms were introduced by the government of Indonesia. In general, they were directed to develop and promote exports of commodities other than oil and gas, particularly manufactured agricultural and forestry products. Revenues from exports of these commodities have been steadily increasing since then and, in 1987, export revenues from these sectors surpassed the export revenue of oil and gas.

An in-depth look at the structure of the import and export figures reveals the following.

- The share of imports of capital goods is close to 20% of the total import values.
- About 70-80% of the imports is from the purchase of capital goods and other major industrial inputs in the form of manufactured commodities.
- Since 1987, revenues from export of other commodities have exceeded from that of oil and gas. But the balance of trade has always been negative for commodities other than oil and gas.

Foreign exchange revenues from export are, therefore, an absolute necessity for acquiring the flow of technology in the form of capital goods, technical services, and commodities for industrial inputs. When demand for export of manufactured products started to develop, the demand for import of capital goods, technical services, and commodities for industrial inputs also accelerated. It implies the importance of devising measures to enhance technological capability and capacity for more resilient economic and industrial development. Within the past decade, efforts in that direction were more seriously considered and undertaken in the development process. In the past few years, there were further indications that stronger linkages between the agricultural and industrial sectors were pursued, eventually leading to improvement of the income level of the majority of the population, as about 55% of the labour force was employed in the agriculture sector.

As compared to the other sectors, since 1983, the growth in the manufacturing sector was more rapid, *albeit* the relatively strong dependence on imports of technology, largely embedded in capital goods. During the on-going development plan (Repelita V), the overall economy is expected to grow in real terms at an average annual rate of about five per cent. Provisional estimates indicate that the industrial sector will grow at the rate of 8.5% per annum, on an average. With such growth, it is expected that the share of the industrial sector in the gross domestic product (GDP) will increase from 14% in 1988 to 17% in 1993. With an expected annual population growth of about 1.9%, the annual GDP per capita is expected to increase from US $424 in 1988 to US $706 in 1993.

Business environment

In the 1970s and early 1980s, expanding oil revenues enabled Indonesia to sustain a policy framework characterized by large public investment in capital intensive infrastructure and industries, together with a trade regulatory regime that stifled competition. The adjustment programme launched in 1983 was designed to promote a more competitive economy, with an increasing role for the private sector and less dependency on the oil and gas sector. At the same time, the government has initiated deregulation in the industrial sector by simplifying and relaxing the multitude of domestic regulations and licensing procedures that constrained the performance of the industrial sector.

In 1986, the number of areas open to private, foreign, and domestic investment was expanded substantially and only some areas, that are announced in what is called 'negative line of investment', were restricted. Foreign investors were also given greater access to domestic capital and financial institutions, and domestic partner ownership requirements were eased, with only 20% of the total US $250 000 required as the minimum investment. To promote and attract more foreign investment, the government provided some tax facilities in the form of tax exemption or delayed payments.

The inflation rate was relatively low during 1988 and 1989, i.e., 5.4 and 5.97% per annum respectively, but went up considerably, reaching close to an annual average of 10% towards the end of 1990. The government is determined to check the inflation rate at five per cent per annum during the coming Repelita VI.

The banking system in Indonesia comprises of a central bank (Bank Indonesia), state-owned and private commercial banks, regional development banks, and other non-banking financial institutions. Some private commercial banks are owned by foreign banks and operate as subsidiaries or branches.

Some dominant characteristics of the national banking system are given below.

- Dominated by state-owned banks.
- Centrally operated.
- Located in the five big cities of Indonesia—Medan, Jakarta, Bandung, Surabaya, and Semerang.
- Grants credit with a high emphasis on the provision of collaterals and less emphasis on credit worthiness.
- Capital equity is relatively small compared to its assets.

To create a better climate for investment, the government has launched a series of policy measures in the banking sector. The banking system since then has slowly undergone shifts towards better operations and appears to be financially healthier. An overview of the terms of loan investment, forms of business organization, and taxation issues is given in Annexure I. Other particular factors considered are dealt with in the following paragraphs.

Beside the previously described parameters that set the environment for transfer of technology, other factors related to business practices are also shaping the environment, since technology transfer

cannot be detached from business activities. An important factor is the protection of intellectual property rights and the patent law of the country.

With respect to protection of intellectual rights and patent laws, one can only say that during the past 10 years the government has undertaken steps and measures to strengthen the system. Act 6 (1982) was issued to replace an existing patent law that was dated from the Dutch colonial era. However, considerable efforts still have to be made. The institutional set-up is still in the process of framing its functions and operations. The government's enforcement apparatus—the judicial system in particular—still requires a great deal of enhancement to be effective and to function properly.

Concerning factors related to business practices, the following quotation can properly reflect the situation.

A number of factors converge to make Indonesia, a challenging (some might even say 'frustrating' or risky) place to do business. The first is rooted in the country's culture. The way business deals are made here is, in truest sense of the word, 'foreign' to many who come to. Indonesia from abroad (including many fellow Asians). Business deals are not so much based on carefully crafted legal documents (though these are certainly drawn up) as they are on the relationships and bonds of trust that arise between partners in a venture.

A second, and related, matter is the state of Indonesia's commercial code, some parts of which dated back from the Dutch colonial era, while others (particularly regarding land rights and transfers) are entangled in a mass of locally-based traditions. The rule of law is still very much in its nascent stages here. As a result, alternative strategies to minimize risk and maximize the room for manoeuvre must be considered.

One clear upshot of these two considerations is that the standard ideas that foreign business people tend to have about being able to resolve serious conflicts and disputes through the pursuit of legal principles, and the enforcement of legal documents in a court of law, can sometimes be of little utility in the Indonesian context. The reasons for this again are again partly rooted in Indonesia culture. Eschewing litigation, the Indonesians prefer to solve disputes through what they term 'musyawarah' and 'mufakat'. These words mean 'deliberation' and 'consensus' and the process often involves mediators and arbitrators who assist the conflicting parties in reaching an acceptable solution.

Another is that the average business person, no matter how skilled and successful in other contexts, is utterly unequipped to make the most fundamental of decisions. Whom should you choose as your partner? What requirements should your partner fulfil? What and who should be avoided? How does one even begin to search? The answer to each of these questions is as different as the investments and business deals themselves. It is for this most

weighty of the business decisions that you must seek advice and assistance. To fail to do so is to court disaster.

3.1.2 The channels and media for technology transfer

The channels for technology transfer depend on where the point of transaction takes place—in the science and technology (S & T) community, in the technology and industry institutions, or in the commodity and services industry. Of the three transaction points, only the last two are under consideration. Possible channels for transfer in the direction of the two industrial institutions are: direct investment, joint venture, licensing, and technical assistance arrangement, whether on a commercial basis or as part of a grant. All these channels are available and the basic features concerning investment have been elaborated in Section 3.1. Description of the technical assistance programme is not necessary, as this type of transfer channel is normally handled by way of simple contractual arrangements. Licensing agreements are usually made as part of the investment arrangement. If it is a standalone agreement, one has to be familiar with the legal aspects, the salient features of which have been described in the preceding section. As was pointed out, the system is still developing and evolving.

3.1.3 Salient features of the recipient

There are basically three classes of recipients, namely, (i) S & T institutions, (ii) professional institutions, and (iii) industrial institutions. Each of these entities has different features basically, corresponding to the roles that each has within the overall technological institution (Figure 1, Appendix I).

The S & T institution

The S & T institution comprises of three basic elements—the S & T information system, the educational system, and the R & D system. In Indonesia, the practical need for such systems, except the educational system, is not really felt by the community at large. As such, there is practically no allocation of resources by the private sector to establish and operate R & D units as well as the S & T information base system in Indonesia. Establishments within the S & T institution in Indonesia are, therefore, almost exclusively government operated or in some cases run by some of the large state enterprises. Private sector R & D is practically non-existent.

Basically, the S & T institution systems are accommodated within five organizational units, namely, the university system, the government R & D organizations, the departmental R & D agencies run by various government ministries, and R & D units of the state-owned enterprises and the private industrial establishments.

As can be observed in other developing countries, the university system (particularly the state universities) is the strongest element of the S & T institutions in Indonesia, in terms of manpower resources, outlook, and idea generating capacity and capability. It must be pointed out that up to this point of time only about five or six universities (all state universities) have such strength. Practically all other S & T institutions in the country are initiated from or by elements of the university system,

and university people are always involved and play leading roles in the process of establishing, and even operating, those institutions.

While the university system has always been playing leading roles in the establishment and operation of the various elements of the S & T institutions, meaningful R & D output from the system itself is minimal. Several factors can be enumerated for, the important ones being:

(i) the heavy teaching load that faculty members have to take due to the tremendously increasing demand for higher education;
(ii) the numerous challenges and opportunities that the faculty members have in applying their expertise outside of the campus;
(iii) the low salary that the government provides to university staff; and
(iv) the very constrained financial resources available for R & D activities.

Besides the university system, comparable R & D activities are undertaken by government research organizations such as the Indonesian Institute of Sciences, BATAN, the National Aeronautic and Space Agency, and several laboratories that are accommodated within a science complex—the National Science and Technology Development Center, known as the PUSPIPTEK, and BPPT. These research organizations, which are not burdened with educational functions, are facing similar constraints as the universities. R & D agencies of the various government ministries and R & D units that are operated by state and private enterprises, such as the State Enterprise for Fertilizer, PERTAMINA, and the PLN are functionally directed towards solving operational problems and to provide technical inputs required for planning purposes. In many cases, their R & D efforts are contracted out to university staff or to other government research organizations mentioned earlier.

At the national level, S & T development is administered by a specially established ministry, and the current ministry is designated as the State Ministry for Research and Technology. There is also a National Research Council that serves as an advisory body to the State Minister for Research and Technology, and another higher advisory body called the Indonesian Academy of Sciences, that provides counsel and advice to the President on national S & T matters.

With an institutional set-up as described above, almost all of the standard, formal government departments, councils, and institutes are in place, defining a system that, in principle, addresses the full range of S & T requirements of the nation. However, as was pointed out previously, there are serious shortcomings in the operation and effectiveness of the system. The single outstanding aspect of the S & T institution, with respect to research and technology development, of the nation is its ability in maintaining the growth and the spirit of the scientific community, without which the country would not be able to reach whatever progress that it has.

The professional institution

In nurturing processes of innovation, professional associations play a key role in accommodating forums of communication among the actors that cut across the R & D and industrial communities. The functioning of the professional institution is therefore an important element in technology transfer

processes, particularly in technology absorption and mastery processes. Unfortunately, the professional institution is functionally weak. Not a single one of the existing professional associations in Indonesia is properly managed and functioning. Except for proceedings of meetings and conferences, one practically cannot find regular publications on S & T subjects produced by professional associations. However, in line with the improving economy of the country, there are trends of improvements within the professional institution itself.

The industrial institution

The industrial institution comprises of two major elements, namely, the technology industry system and the commodity and services industry system. Although horizontal (international) technology transfer also occurs at the other institutions (S & T and professional institutions), it is in the industrial institution where the need for externally acquired technology is strongly felt. This is mainly because of its tangibility and its observed effects, which becomes clearer when the transfer process is taking place in the commodity and services industry.

In terms of monetary value, the flow of externally acquired technology is the highest in the commodity and services industry. Such phenomena are generally observed in developing countries (Appendix). Less intellectual sophistication is required with such transfer process. This is because the technology is already well packaged and 'frozen' in functional and operable mediums such as capital goods, very detailed product design description and specifications, and operating instruction manuals, and usually is complemented by training programmes.

Such technology transfer processes as exemplified in the car, fertilizer, and cement industry, seem to be effectively taking place in terms of the first level of technology absorption, which is the mastery of operating the technology by way of adaptation of the acquired technology. No serious problem has been observed in this process. The mastery for operating the technology has in fact stimulated further levels of the absorption processes, where what is known as progressive manufacturing process is taking place. Progressive manufacturing process implies that in the course of operating the transferred technology, the flow of technological components that originate from the source is progressively deleted and replaced by locally produced or generated components.

In the machinery industry, the process takes place in stages, starting with gradual replacements of imported parts, and eventually, following a planned schedule, the development of new product designs takes place. In the process industry, such as energy or chemical plants, the stages that take place are plant construction based on a given design, the development of the design for construction, and eventually, the design of the whole system as well as the construction of the plant based on that design. This process also stimulates other transfer processes for the production of selected process equipment, following the progressive manufacturing scheme as previously described.

The described processes have taken place in many sectors of the manufacturing industry, and has resulted in the deepening of the structure of the industrial system of the country. Starting with the commodity industry, it goes to the technology industry, where engineering design, technology development, and packaging are gradually evolving. The evolution that takes place stimulates the develop-

ment of technology industry increasingly, and with that the demand for R & D activities is also evolving. These trends are currently observed, although they are only in the initial stages.

Concluding remarks

The above elaboration shows that technology mastery processes, initiated with the acquisition of externally acquired technology, are taking place satisfactorily. With whatever limitation in human resources that the country has, there is adequate capability for the absorption process. The hampering factors are not in the domain of the level of capability (either potential or real) but in terms of capacity, regulatory infrastructure, and some other parameters that set the environment for transfer.

3.2 Technology transfer issues in the power sector

In discussing technology transfer issues in the power sector, first a review of the development of the power sector is made. Issues pertinent to this study will then be identified and discussed. Of those identified issues, particular aspects that are most relevant to be considered in analysing the problem of technology transfer of the cogeneration system will be pointed out and assessed.

3.2.1 Review of the power sector development

The Indonesian power sector comprises of: (a) the PLN, with 9171 MW installed capacity (1991); (b) captive plants installed by private and state owned companies for their own use, with around 9000 MVA capacity (1990); and (c) a large number of co-operatives and small private establishments which generate and distribute electricity to rural areas. The sector is regulated by MOME through the Directorate-General of Electric Power and New Energy. The Directorate is responsible for policy formulation, licensing of electricity undertakings, and general supervision of the power sector.

PLN

PLN is a public corporation assigned to act as the holder of state authority in the development of the power sector throughout the country. Its responsibility includes planning, construction, operation of power supply, and distribution facilities. To support its development, PLN established four agencies, namely, the Engineering Service Centre, the Education and Training Centre, the Electric Power Research Centre, and the Management Service Centre.

In line with the economic development of the country since the seventies, the electric sector has been growing rapidly. Between 1970 and 1991, PLN's installed capacity and power generation grew at an average rate of 14.4 and 16% respectively per annum. The power generating facility of PLN in 1991 was 9171 MW, comprising of oil (44.5%), hydro (24.5%), coal (19%), gas (10.9%), and geothermal power plants (1.5%), in decreasing order. PLN's supply system consists of over 1000 individual systems, ranging in size from 100 kW to 4700 MW. Almost 70% of PLN's total capacity is located in Java, the most densely populated island of the country.

PLN's power production in 1991 was around 37 500 GWh. In addition to this power generation, PLN also purchases power from other entities. The share of purchased power on PLN's production (self-generation and purchased) tends to decrease from a substantial 25.5% (489 GWh) in 1970 to only 2.2% (843 GWh) in 1991. PLN's customers total about 10 million, comprising of four sectoral groups, namely, household (87%), industry (0.3%), commercial (3.6%), and public service (2.4%). Up to 1986, the household sector had been the largest consumer of PLN's supply. Since then this position nas been taken over by the consumption of the industrial sector, indicating a shift in electricity consumption to productive uses. Between 1981 and 1991, the relative share of household sector consumption decreased from 44 to 33% with a corresponding increase in the share of industrial consumption—from 27 to 51%. However, PLN's relative share in industrial electricity consumption is still relatively low, whereas, in 1991, it was around 42%; the rest being accounted for by captive generation facilities operated by industrial plants. In the last ten years, the demand from PLN's industrial customers grew at an average rate of 22% per annum. In keeping with the rapid industrial growth, industrial electricity demand is expected to continue at a high rate at least in the next ten years.

According to PLN projections, the Indonesian power demand in Repelita VI (1994-1998), Repelita VII (1999-2003), and Repelita VIII (2004-2008) will grow at a rate of 17, 12, and 8%, respectively. To meet such demand growth, PLN installed capacity will have to increase so that at the end of each of the above mentioned Repelita, PLN's capacity would reach 25, 40, and 57 TW, respectively.

One of PLN's impressive achievements is its rapid rural electrification programme. The programme was launched in 1978 and, in 1979, PLN electrified a total of 280 000 rural households in 2244 villages. In 1991, the total rural customers of PLN reached a figure of 6.3 million, spread over 23 000 villages. With the total of rural households at 28 million and the total of the village at 62 000 (in 1990), the rural electrification ratio, in terms of household and village, are 22.5 and 37% respectively. However, in spite of its rapid development, PLN is only able to serve around 70% of the urban households and 22% of the rural households (1990), whereas it is estimated that around 90% of urban households and 60% of those in rural villages could afford to purchase electricity.

Captive power

The demand of electricity which has not yet been met, in terms of quantity as well as quality, in the industrial sector, which rapidly grew in the late seventies, has led to the rapid growth of industrial captive plants. Excluding large captive plants (more than 200 MW per plant), the total installed capacity of captive plants has grown from 2385 MVA in 1978 to 5775 MVA in 1989. Almost half of the latter are also connected to PLN and operating on a stand-by basis. Including large captive plants, the total captive power in 1989/1990 was 9000 MVA and about half of them are plants with installed capacity of at least 10 MVA per industry. The industrial captive plants supply accounted for around 58% of the total industrial electricity consumption (1991); the rest being supplied by PLN's grid.

Unlike PLN's electricity system where it is concentrated in Java, more than half of captive plants are installed outside Java. Captive generators in Java are mainly diesel plants (about 80%). Outside

Java, captive power generators are more evenly mixed. It comprises of diesel (44%), natural gas (27%), hydro (17.7%), biomass (6.6%), and oil/coal-fired power plants (4.2%). Biomass power plants are used in industries processing agricultural products, like palm oil and sugar industries, and in some wood processing industries (sawmills/plywood mills, etc.). In palm oil and sugar industries, the majority of these biomass plants are operated as heat and power cogeneration systems. The above described industrial captive plants, where the majority of them are thermal plants, suggest significant cogeneration potential in the country.

Rural electric co-operatives and micro-enterprises

Lack of PLN electricity supply in rural areas has led to the establishment of rural electric co-operatives and micro-enterprises. In 1990, there were a total of around 20 rural co-operatives with total capacity of about 265 MVA, serving about 40 000 rural households. According to a 1986 economic census, there was a total of about 17 000 small private utilities in 1986, each operating a generator of one kW or more, with at least 10 customers. The total installed capacity of the micro-utilities was about 180 MW. Most of these utilities were household establishments operating without licences, serving low quality electricity and charging high tariffs (4–8 times higher than PLN tariff). With such service, these utilities offer no competition to PLN, and usually disappear when PLN reaches the region.

With the objectives of reducing PLN's manpower deployment and to support rural development, schemes enabling the participation of rural co-operatives (KUD) in electricity undertaking, in the form of sub-contract services (metering, billing, line installation, or managing/operating PLN's isolated systems) and rural utilities, have been formulated. In 1990, the total number of KUDs that were involved in the electricity undertaking were around 600 000, mostly functioning as PLN's service contractors.

Power shortage

The rapid growth of the industrial sector and PLN's inability to keep pace with such growth, primarily due to financial constraints and delayed expansion projects, has been the cause of the prevailing power shortage. In Java, i.e., the region that forces the most shortage, the additional demand of the industrial sector in 1991/92 was about 2500 MVA, while, in the same year, PLN could only serve additional supply of around 800 MVA. The shortage was felt more during the long dry season in 1991 when the hydro plants (which meet 22% of Java's capacity) could not operate optimally. At present, the reliability of the Java supply system is actually critical, as, at normal conditions, the capacity reserves of PLN plants are only around 16%.

In an attempt to avoid delays in the completion and operation of a set of vital industrial development projects, the government has been advising new and large industrial estates to install their own power generation system as PLN would be able to provide the required additional supply only in 1993 when the large combined cycle plant in East Java would come on-line. To expedite the availability of power supply, these industrial estates will primarily use diesel power generators. Considering that

diesel fuel supply is to some extent constrained, and also because it is one of the highly subsidized fuels, these industrial estates will have to pay for the imported fuel at the international price. This scheme aims to prevent additional budgetary burden for fuel subsidy that has to be borne by the government.

Private power generation

A relatively new scheme to promote private sector participation in the electricity development of Indonesia is by promoting private investment in the power sector. The Government of Indonesia (GOI) has taken initiatives toward this direction and is currently arranging some private power generation projects. In addition, GOI encourages private investments in those situations where private generation is economically competitive to PLN's grid, such as (i) heat and power cogeneration, (ii) the utilization of waste material for power generation, and (iii) the development of large-scale power plants to meet specific industrial requirements and augment PLN supply.

Although the regulatory foundations for private participation (including co-operatives) in power supply have been established since 1985, by the issuance of Law 15/1985, there have been no follow-up regulatory means. The existing guidelines are provided in a Directorate-General decree, issued in 1983, but this was issued with reference to Government Regulation No 36/1979 and a subsequent regulation on electricity undertaking licensing issued by MOME, known as Ministerial Regulation 11/1981. They therefore are not quite in tune with the newly issued law on electricity supply and distribution. Provisions regarding pricing and purchase guarantee by PLN have not been spelt out clearly.

To cope with the evolving issues and developments concerning private electric utility stipulated in Law 15/1985, especially after the government encourages the private sector to participate in power supply undertaking, a specially assigned team, designated as the Private Power Team, was established by the government in June 1990. The team is an inter-ministerial committee chaired by the Director-General of DGENE and includes officials from PLN, the Directorate-General of Oil and Gas, Investment Co-ordination Board (BKPM); BPPT, Directorate-General of Taxation, and the Directorate-General of Monetary Affairs of the Ministry of Finance.

This team is mandated with a broad task of developing the necessary implementation guidelines for the operation of Law No. 15/1985, and while the guidelines are still in the making, they also have to handle incoming project proposals and undertake negotiations with the project proponents, to come to an ad hoc agreement concerning the investment and operation schemes, as well as the sales and price arrangements.

Presently, this team is processing the first private power project i.e., a 1200 MW power plant in Paiton, East Java, possibly under the build, own, and operate type of contract. It is expected that lessons learned from this project could be further studied and used as a valuable input in the process of developing guidelines for implementing Law 15/1985. The team has a very important role and has to work under heavy pressures, since private sector participation is being eagerly promoted by the

government, to overcome the power shortage problem. Without private sector participation, it would be impossible to overcome the problem, since the amount of the needed capital is not within the available resources that the government can acquire.

It is expected that 60% of the required additional generation capacity for Java, which until the year 1999 is estimated to be 1300 MW, will come from private investors. Following the Paiton project mentioned previously, in 1991, GOI has invited private investors to take up investments for the development of another five power generation projects of various capacities (25–600 MW) and fuel types (geothermal, coal, and peat).

3.2.2 Technology transfer issues

At the national level, there are nine units that are involved in the processes of technology transfer. They are (1) PLN, (2) the industry, (3) BPPT (4) the Directorate-General for Power and New Energy, (5) the Department of Co-operatives, (6) the rural electric co-operatives and micro enterprises, (7) university and government R & D organizations, and (8) non-government community services organizations.

In terms of the scope of functions being undertaken, these units can be categorized into the following groups.

(i) Those in charge of determining the policy and guidelines that influence the choice of technology, where the particular units are BPPT, the Directorate-General for Power and New Energy, and the Department of Co-operatives. Of the three government agencies, BPPT has a dominant role in technology selection and evaluation, particularly for government investment.

(ii) Organizations that conduct R & D disseminate technology by way of demonstration projects. Basically the types of technology dealt with are small-scale, renewable resource-based energy systems, energy conservation technologies, and technological software. University and government R & D organizations, and some units of the agencies belonging to the first category are elements of this category. Non-government and community service organizations are involved mainly in technology dissemination through demonstration projects.

(iii) The most important are the enterprises, large and small, that are directly involved in the investment and operation of power systems, and the enterprises that manufacture machinery and equipment, as well as those that provide technical services such as construction, installation, repair, and maintenance. Some of the major units involved are PLN, the captive power generators in the industrial and service sectors, and power machineries/equipment manufacturers.

The bulk of technological flow goes to the third category, where PLN and industrial captive power generators dominate. The mode of transfer is mainly by way of investment, and the technology being transferred is embedded in capital goods, engineering design, and construction services. The level of mastery in the absorption process has only reached the ability to operate and maintain the installed system, part of the construction work, like the structural part, and manufacturing of licence

Table 3. Production of diesel engines and electricity generators (units)

Year	Diesel engine	Generator
1973–74	2 000	–
1978–79	30 400	–
1983–84	52 775	3771
1988–89	32 424	6570
1989–90	46 500	7690

Source. GOI. President's speech before the House of Representatives, 16 August 1990.

based static equipment such as boilers, low pressure heat exchangers, and burners. List of equipment and parts of power generator systems that have been manufactured locally are presented in Annexure II.

Energy equipment manufacturing

Technical assistance is still required in equipment manufacturing—in production, supervision, and engineering design. The design and prescriptive aspects of the existing equipment manufacturing industry are completely adapted through the licensing mechanism. The level of mastery that has been reached is really a reflection of the infancy of the machinery and equipment industry in the country, which has only reached plant assembling and operation and structural works. Processes that require forging and heat treatment have just begun to develop. So is the case with works involving skills and expertise on precision mechanics.

The rapid growth of the power sector has contributed significantly to the investment stimulation in the energy equipments and machineries industry However, the level of demand in terms of number of units is presently still too small to make additional domestic or joint venture investments attractive. Production facilities in place are still considerably under-utilized, especially, those producing large scale equipments (Table 3).

An area, where transfer of technology, related to electricity production is economically attractive, is in the production of medium and small capacity diesel engine and electricity generators, because of the large area of application in productive activities and also because of the unmet demand for electricity. The demand for high capacity units has not reached a level where investment for domestic production is attractive. The level of technological mastery in the commodity producing industry has only reached assembling operation of licensed design. Most of the essential components still have to be acquired from the source. Economic considerations do not justify further stages of progressive manufacturing scheme. Table 3 provides some illustration on the development of diesel engine and electricity generator industry.

Engineering design and construction

Other areas, where transfer of technology is economically attractive and processes of absorption are taking place, are engineering design and construction. The activities normally undertaken are in

connection with the implementation of power generation and distribution projects, whether as part of an industry construction project or development projects of PLN or as private power generators.

Except for diesel powered generators, activities in engineering design and construction are undertaken by foreign firms in co-operation with local partners. By government regulations, any foreign engineering and construction firm has to agree to such an arrangement. In an evolutionary manner, as the capability and capacity develop, local consultants and contractors take up the role of the main contractors.

Technical studies and services

Technical studies for feasibility and preliminary configuration of power plants are undertaken mostly by domestic technical resources. PLN, in particular, has in-house capability for such studies. Engineering capability for energy conservation studies and services for industry and commercial sectors have also begun to evolve in the past 10 years, but the progress is hampered by the subsidized prices of refinery products, natural gas, and electricity, which are the major components of the energy supply.

The practices of those studies and services are based on externally acquired methodologies and techniques, whereby the support of computer based software has a dominant role in accelerating the level of performance. However, there is a glaring deficiency of development efforts in generating those techniques and methodologies, which is either computer based or not. The practised techniques and methodologies are two or three generations behind the state-of-the-art techniques, and, therefore, have not been able to address current issues where, for example, conserving measures in the demand sectors are to be accounted for in supply planning.

Waste heat recovery systems, commonly practised in the process industry, have somehow been alien to those dealing with the power sector. Combined cycle and cogeneration are only widely discussed and put in practice in the past five years. The role of donor agencies is dominant in the introduction of such technologies.

Application of the non-conventional mode of electricity supply

Following the oil shock in 1973, a wave of grants and technical aids swept the developing countries, including Indonesia, where the non-conventional mode of power generation technologies was promoted by way of introducing or reintroducing the forgotten technologies. Except for the solar photovoltaic and fuel cell based systems, the non-conventional aspect is not really the power generation itself, but the primary energy that is exploited or utilized to drive the prime movers of the power generation system. Among the array of promoted technology, the biological digestion of biomass wastes, thermal gasification of biomass, windmills, mini and micro hydro turbines, and solar photovoltaic cells are gaining widespread attention in Indonesia.

Development works, adaptation, and straight demonstration activities of the technology are undertaken by the universities, government R & D organizations, and even some government adminis-

trative offices dealing with energy. In terms of the institutional structure of technology (Appendix), the entry point for the transfer of the mostly externally acquired technology is at the S & T institution. The area, where the technology is being tested for application, is the rural community or small and relatively primitive industries.

While there are R & D groups that reach high levels in the mastery of technology, the functioning of the technology in application is not taking place on a practical basis. This could be accounted for by three factors.

(i) The channel of transfer is through the R & D institution. With limited resources that the country can allocate for R & D purposes, the dissemination processes are mostly stopped when the external funding is receding and discontinued.
(ii) The area of application where the technology is directed, i.e., rural environment and small/primitive industry, lacks the nurturing capacity for the appropriate functioning of the technology.
(iii) The prices of established energy commodities, against which those technologies are to compete, are distorted mainly due to the subsidy.

With a few exceptions, only when the technology is robust with respect to requirements for technical support, and when there is a combination of aggressive promotion by foreign donors and government support, the technology would be able to function. But this is, in fact, a form of subsidized scheme. Such a situation has been recently observed with the promotion of small solar panels for individual rural families. While small solar photovoltaic panels seem to be the only technology on the non-conventional mode of electricity generation being dealt with, the level of technological mastery of technology, relative to the others that were previously mentioned, is the least. The only technology, where a high level of mastery has been achieved and can compete with established systems survive under minimal technological support system, is the mini hydro turbine. Two other technologies, that have been mastered are the biological digestion of biomass wastes and the thermal gasification of biomass. They can also compete against established systems, but both require certain levels of technical efforts to operate. The level of requirement in biomass thermal gasification is also considerably much higher.

Concluding remarks

The discussion concerning the technology transfer issues in the power sector focuses on the absorption aspect. Emphasis on this aspect is being made since other relevant aspects have been substantially covered in Section 3.1.1. Also, referring to the discussion on the development of the power sector in Section 3.2.1, a set of conclusions that is most relevant in seeking an opportunity which is favourable for the application of cogeneration system can be made.

(i) In line with the country's economic development which is marked by the rapid growth of the industrial sector since the past two decades, the supply of electricity has been growing at a high

rate. Yet there is a sustained unmet demand. Such a situation has led to the rapid growth of industrial captive plants, either operating on a continuous or on a stand-by basis. The majority of the captive plants are thermal plants. This suggests the considerable cogeneration potential in the country.

(ii) The regulatory foundation for private participation in the power supply has been established although the required specific and detailed guidelines for the implementation of regulations are still to be prepared. Private investment in those situations where private generation can be economically competitive to the utility grid, like that of the combined heat and power cogeneration, is encouraged by the GOI.

(iii) The most effective route of technology transfer, in terms of having the technology operating and responding to needs, is to the industrial institution, where the flow is dominated by capital goods and/or packaged and ready-to-use technological prescriptions. The process of absorption towards technological mastery, however, is slow as compared to other routes.

(iv) For equipment manufacturing, there is less opportunity to develop economically attractive investment in the production of large scale units. The market is easily saturated, and can easily lead to under-utilization of capital.

(v) With reference to the above conclusion, if one wants to achieve an objective through the introduction of technological means, e.g., improvement of efficiency of the energy system by way of promoting the wider functioning of the cogeneration system, it would be more appropriate not to focus on the manufacturing of large scale equipment.

(vi) To avoid unnecessary failure, it is important to identify areas for the functioning of the technology, that have the capacity to nurture the growth of the application of the technology and its further mastery.

(vii) Considering the average manufacturing capability, it is best that the initial effort should focus on developing manufacturing of static devices, such as waste heat boilers and heat exchangers. Then, through a progressive manufacturing scheme this can move towards the manufacturing of more sophisticated production procedures, such as the manufacturing of rotating equipment and devices that require a wider capability base in precision mechanics, heat treatment, and forging.

4 TECHNOLOGY TRANSFER OF COGENERATION SYSTEMS

After elaborating pertinent background considerations in the preceding chapters, we will deal with the key questions to be addressed in analysing the technology transfer of cogeneration systems. As was pointed out at the outset, the investigation focuses on responding to the following questions.

(i) What opportunities are available for the wider application of cogeneration systems in Indonesia?

(ii) What is and would be the role of international transfer of technology (ITT) to Indonesia in influencing the wider application of cogeneration systems?

(iii) What would be necessary to promote a better environment for such a transfer process to occur?

4.1 Opportunities for cogeneration in Indonesia

Indonesia has launched energy conservation programmes as one of the important components of the national energy policy. Private power generation schemes, through which cogeneration systems are implemented in some cases, have been introduced by the issuance of the Private Power Generation Law. Private investments in those situations where private generation is economically competitive to PLN's grid, like combined heat and power generation, is encouraged (see Section 3.2). The energy policy, as formulated, is therefore supportive towards efforts for the utilization of cogeneration systems. The effective implementation of the policy, however, has not been observed. The major barrier is the prevailing subsidized price of energy, particularly the price of the petroleum products and electricity and, with respect to private power generation, the lack of specific and detailed guidelines for the implementation of the regulation.

Potential consumers of cogeneration system products, i.e., electricity and heat, are the industrial and commercial sectors. If one extends the analysis focusing, not strictly on heat and power cogeneration, but also considering the wider problem of waste heat recovery from power generation units, there is also considerable opportunity for the application of the technology in the power sector—to enhance the production of electricity generated by diesel powered plants. And, since Indonesia is a tropical country, there is practically no demand for residential space heating.

4.1.1 Overview of the opportunities in various applications

Opportunities in the industrial sector

Within the last decade, energy consumption of industrial sector has been the largest among sectoral energy consumers (commercial, transport, and residential sectors). In 1990, the industrial energy consumption accounted for about 40% of the total commercial energy consumption. Electric power demand for the industrial sector is supplied by PLN and industrial captive plants. At least, within the last two decades, electric power supplied by the captive plants was higher than that by PLN. In 1991, the captive power plants supplied about 58% of the total industrial electricity demand. Although the share of PLN in the industrial electricity supply has been increasing with its rapid capacity expansion in the last decade, one cannot expect that the growth of supply from PLN will be able to keep pace with the growth of the demand for electricity from the industrial sector. The importance of the power plants will continue to remain.

Most of the industrial captive power generators are thermal based plants fuelled with refinery products. More than half of the thermal plants capacity are diesel power generators. Industrial process heat requirements are supplied by respective industries. Most of the industries that operate captive plants, and have process heat demand, do not practice cogeneration. The production of electricity and process heat is performed separately. However, cogeneration systems have been, for a long time, implemented as a standard energy supply system in palm oil and sugar industries. Cogeneration, or otherwise optimal waste heat recovery systems, has also been practised in the basic chemical industries and refineries.

Opportunities in the commercial sector
In the commercial sector, particularly in commercial buildings (hotels, shopping centres, etc.), electricity is supplied by PLN. For reliability reasons, however, such establishments, especially large commercial buildings, also maintain diesel power generators operated on a stand-by basis. Heat energy demand, particularly for water heating, exists in classified hotels. They usually operate electric or gas heaters or diesel fuelled boilers for their hot water needs.

Opportunities in the power sector
In addition to the industrial and commercial sectors, opportunities for the utilization of cogeneration systems also exist in the power sector. There are two possible schemes or modes of cogeneration implementation in this sector. The first scheme is the utilization of heat energy released by PLN's thermal plants to supply process heat demand of adjacent industries. While such a scheme is technically feasible, the implementation will not be easy as such schemes would require inter-institutional transactions. In the second scheme, heat recovered from exhaust gas and water jackets of PLN's diesel plants is utilized to produce steam which subsequently will be used for power generation using steam turbines. The second scheme is, by definition, not a cogeneration system since the ultimate product of the waste heat recovery system is electricity rather than heat, and is commonly designated as a combined cycle operation.

4.1.2 Potential capacity of cogeneration application

Industrial sector
Commercial energy consumption in the industrial sector in 1991 was estimated to be around 17 mtoe. About half of it consisted of natural gas and coal, which were primarily consumed by three major industrial sub-sectors, namely, fertilizer, steel, and cement industries. Although these industries are large energy customers, they have to be excluded from the analysis since cogeneration or, at least, waste heat recovery systems have been widely applied. The same applies to the pulp and paper industry that consumed around one per cent of the total industrial consumption.

Among the remaining industries, the significant commercial energy consumers are the textile and tyre industries. The textile industry consumed about four per cent of the total commercial energy for the industrial sector or about 0.7 mtoe in 1991. Half the fuel consumption in this industry is used for electricity generation from diesel power generators and the remaining is used primarily for steam generation. The power generation of this industry is estimated at around 140 MW. Assuming that the electricity and heat demand of the industry is supplied by way of cogeneration, saving in fuel consumption equivalent to 42 MW could be achieved. The tyre industry consumption accounted for around one per cent of the total industrial energy consumption (0.2 mtoe) in 1991. In this industry, fuel is consumed for both power and steam generation in about the same proportion. As in the case of the textile industry, the tyre industry has great potential for the application of cogeneration technol-

ogy. The cogeneration potential capacity of the tyre industry is estimated to be about 40 MW. If this potential is utilized, fuel consumption equivalent to 12 MW could be reduced.

The wood processing industry is a significant energy consumer in Indonesia. It accounted for about one per cent of the total commercial energy consumed by industrial sector. Among the wood processing industries, the major energy consumers are plywood mills and sawmills. Plywood mills require both electric power and process heat. The total electricity demand in the plywood industry is around 125 MW. About 80% of this demand is supplied by captive diesel plants and the balance is supplied by the PLN grid or by the captive wood-fuelled steam turbine generator. Process steam is generated in boilers using waste wood available from the respective plants. The recovery rate of plywood mills in Indonesia is around 50% and the balance ends up as waste. By using steam turbine cogenerators, the available wood wastes are sufficient to supply the electricity and the heat demand of the mills. Focusing only on the replacement of the diesel plants, the cogeneration potential of plywood mills is estimated to be around 100 MW.

Aside from the plywood mills, there are also cogeneration potentials in sawmills, particularly the large ones, as they require both electricity and process heat (for drying). As in the plywood industries, electricity demand is generally supplied using diesel power generators while the heat demand is supplied by wood or diesel oil fuelled steam boilers. The total power generation in large sawmills was around 140 MW in 1985. The log conversion ratio of sawmills is around 0.55 on the average and the balance ends up as sawmill waste. By utilizing cogeneration technology, it is estimated that wood waste available from the mills would be sufficient for supplying both electricity and heat demand of the mills. Assuming that all diesel plants at the sawmills are replaced by combined heat and power generation systems, the cogeneration potential at sawmill industry is estimated to be around 140 MW.

Commercial sector

Classified hotels have the potential to utilize cogeneration systems for their electricity and hot water needs. There are around 430 classified hotels in the country, of which 69 hotels are rated as three-star hotels or higher, with following break-up: 44 three-star hotels; 15 four-star hotels, and 10 five-star hotels. These hotels normally get their electricity supply from PLN and have diesel gensets as stand-by systems. The total stand-by unit capacity of 69 hotels is estimated to be 25 MW, as the cogeneration potential. If and when this potential is utilized, an additional PLN supply capacity of 25 MW (i.e., the avoided supply of PLN) could be created and fuel consumption for fulfilling the hotel's thermal needs equivalent to 7.5 MW could be saved.

Power sector

PLN. PLN has around 1800 MW diesel plants. If they were retrofitted with waste heat recovery systems and operated as steam topping combined cycles, then there would be an additional capacity of 540 MW, based on the assumption that cogeneration systems could save fuel consumption up to 30%.

Captive plants. The total capacity of the existing industrial stand-by (diesels) units is estimated at 2100 MW. If and when those were operated, as diesel combined cycle power generators, to supply their own demand and sell excess power to PLN, the latter could supply additional electricity of 2730 MW; i.e., 2100 MW of avoided supply from PLN to those industries and 630 MW of additional capacity due to the purchase of electricity generated by captive plants operating diesel combined cycle power systems.

The total capacity of captive diesel power plants currently operating is 2100 MW. If and when these units, excluding diesel plants with cogeneration potential that has already been discussed (which is about 420 MW), were converted into diesel combined cycle power units, the capacity would then increase to about 2184 MW. This would create an opportunity for PLN to acquire an additional electricity supply capacity of 540 MW.

Industrial estates. According to the government (i.e., the Directorate-General of Electricity and New Energy) estimate, the additional electricity demand for industrial complexes within 1989–1994 in Java is around 1300 MW. Assuming that PLN could supply only one half of that and the rest would be supplied by captive plants, the cogeneration application in these industrial estates would amount to 650 MW.

4.1.3 Avoided CO_2 emissions potential

The environmental benefit of cogeneration systems over conventional ones is that the former have a better overall conversion efficiency. For a given input, more energy service could be generated when the cogeneration system was used. Assuming that the increment of the energy service output must otherwise be generated by thermal systems, the amount of specific emissions that could be avoided is in proportion to that increment.

The total capacity of existing power generators at the above mentioned industrial, commercial, and power sectors, where cogeneration systems are to be utilized, was estimated at about 6675 MW i.e., 445 MW in combined heat and power generation and 6230 MW in the diesel combined cycle mode. If the combined heat power generation potential was utilized, fossil fuel consumption equivalent to around 300 MW could be saved i.e., from fuel substitution in wood industry, and conservation in textile and tyre industries. If the diesel combined cycle potential was utilized, an additional capacity supply of 4650 MWe could be made available. Of this capacity, 2775 MW is due to the supply of captive plants in the new industrial complex and the operation of stand-by power units at the industrial and commercial sectors. The balance is due to the application of cogeneration technology at those captive and stand-by units.

If and when the above potentials were fully utilized, and assuming that the corresponding demand would otherwise be supplied using conventional diesel power systems and diesel fuelled steam boilers, emissions of around 8.4 million tonnes of CO_2 per year could have been avoided. This avoided CO_2

potential accounts for around 6.5% of total CO_2 emissions from the Indonesian energy sector which was estimated at about 130 million tonne per year in 1990.

4.2 The role of ITT and the transfer mechanism

The presence and the functioning of cogeneration systems in various industries in Indonesia have taken place not because of the particular choice for that technology, but because the systems were offered as part of the technology package of the whole plant. This has been the case with cogeneration systems that are found in some major chemical plants.

For agro-based processes such as palm oil and manufacturing sugar refining, the use of the technology was introduced during the colonial era. When there was a boom in plywood and wood products manufacturing in recent years, most of the plants were not using the cogeneration system, although the plants needed both heat and electricity. While the plants use biomass to fuel their steam generation plants, their electricity requirements are supplied by diesel power plants.

Apparently, the advantages of having a cogeneration system are not quite appreciated, due to several reasons. First, refinery products are easily available at low (subsidized) prices. Second, while the notions about cogeneration systems are familiar to the business owners, they apparently do not quite comprehend what that system is, and therefore perceive the technology as being too complicated or too expensive, or otherwise is not regarded as a proven technology. Hence, considerable efforts have to be undertaken to familiarize and demonstrate the technology. This is where, in the first stage, the international inputs are required, and, therefore, the role for promoting technology transfer processes for cogeneration systems in the country is important.

Several channels have to be exploited in the process, ranging from information dissemination processes in the form of seminars, workshops, and training to further stages of dissemination in the form of real world demonstration, and investments in technical services and devices manufacturing the elements of the cogeneration systems. As far as the efforts to develop domestic capability and capacity to support the functioning of cogeneration technology are concerned, there are two technological components that should most appropriately be taken as the media to initiate the establishment of such capability and capacity. These are cogeneration systems designs and licence based production of stationary components, such as efficient heat exchangers and waste heat boilers. More complicated system components and devices like the steam turbine could follow at later stages. If and when such cogeneration engineering business firms are functioning, they have to include training the customers also as a part of the delivery function.

Referring to the analysis on the opportunity for cogeneration technology (Section 4.1), an area where efforts could economically be interesting and attractive is the retrofitting of existing diesel power plants, for the production of process heat, as well as power generation capacity enhancement by way of utilizing the recovered waste heat for the combined cycle operation. The latter scheme could have meaningful contributions to the current power shortage problem, particularly in the island of

Java. Another prospective area is the revamping of steam generation and power plants in plywood mills that currently utilize heat and electricity, but are not using the cogeneration systems.

4.3 Developing conducive environment

In search of viable and feasible initiatives to promote and support the implementability of the policy on energy, particularly with respect to energy conservation, whereby the application of cogeneration technology can have significant contribution, a set of factors for developing conducive environment will be identified.

Having most of these factors in place, potential areas for the wider functioning of cogeneration systems (Section 4.1) can be taken as targets of implementing the system. Two basic criteria have to be considered in the final selection.

(i) The dimension of the beneficial impacts that can be gained at the national level, as measured in terms of the extent of contribution that such endeavours would have in realizing the objectives stipulated in the policy on energy.
(ii) The economic feasibility and profitability, and therefore the attractiveness to business enterprises to implement cogeneration systems, or to venture into the business of delivering cogeneration systems.

In terms of achieving the objectives stipulated in the policy on energy, the particular criteria that needs to be considered are that the investment to implement cogeneration systems and establishment of business ventures for delivering such systems have features outlined below.

(i) Economically and financially justifiable.
(ii) Must respond directly to the most relevant issues in the energy sector in Indonesia—the increasing level of consumption of refinery products and the deficient supply of electricity.
(iii) Are implementable without aggravating the balance of payments situation of the country.
(iv) Prevented from any scheme that will sustain the energy subsidy or lead to the wider spectrum of energy supply systems requiring government budgetary subsidy.
(v) Nurture the strengthening of domestic technological capability and capacity, particularly supporting the development of energy industry that includes the manufacturing of energy devices.

There does not seem to be any problem in satisfying the above criteria by taking cogeneration system as an investment theme. In fact, investments in engineering firms to undertake cogeneration system design and device manufacturing, and for implementing cogeneration systems in various sectors (the industry, commercial services, and the power sector) will lead to the achievements of the objectives implicitly and explicitly expressed in the above criteria.

In terms of economic feasibility and attractiveness, while the general policy on energy is clearly supportive, there is still a need for changes in the current policy on capital investment financing, taxation, import duties, and most important of all, energy pricing. Except for energy pricing, one can

anticipate that the government will perceive such policy changes. Since 1983, the government has been taking continuous action to direct the economy of the country to be more efficient, and is still continuing to do so.

However, an important element to set such a drive for policy changes is still required. There has to be a thorough and convincing analysis that indicate the benefits of making the desired policy and regulatory changes that would, among others, promote energy conservation in general, and the functioning of cogeneration systems, in particular. The results must be followed up by the dissemination of information presenting the technical and techno-economical aspects of cogeneration systems. These are directed to the business community. Since the government is the main object of the 'advocacy' for policy changes, effort has to be taken by some entities having the necessary resources to do so. Some inputs from international funding agencies or other supportive agencies are required. Carefully designed demonstration projects in various applications, through the risk-sharing scheme between the sponsoring agency and the recipient of the demonstrated system, will enhance the appreciation of implementing cogeneration system.

To sum up, the parameters for the development of conducive environment for the wider functioning of cogeneration systems are:

(i) information dissemination through workshops, training, demonstrations, and analysis of work that will create better understanding and appreciation about the technicalities and the economics of cogeneration systems;
(ii) technical and engineering capability development in the operation, manufacturing, and design of cogeneration systems and devices through appropriate technology transfer channels, and mechanisms involving capable technical institutions and business enterprises;
(iii) regulatory measures to provide tax incentives for capital investment and import tariff facilities to business ventures that deliver goods and services for the functioning of energy conserving systems in general, and cogeneration systems in particular; and
(iv) available financing facilities that are significantly supportive to investment in business ventures in the area of energy conserving efforts.

5 Conclusions and recommendations

The following conclusions can be drawn from this study.

(i) In the energy development of the country, electricity supply capacity has been growing at very high rates, yet there is sustained unmet demand. The current estimate is that for the coming years, the average demand growth rate will be around 17% per annum for the period 1994–98, declining to 12% during 1999–2003, and in the following Five Year development Plan (2003–2008) may, further, decline to an average of eight per cent per annum. Even though there is

a declining trend in the projected demand growth rates, the figures are very high. Most of the power demand is concentrated in the Island of Java.

(ii) Oil and natural gas both play determining roles as sources of foreign exchange revenue, and also because of declining reserves, the availability of oil and natural gas will be limited. The power sector is, therefore, anticipated to be dominated by coal based generation plants. Such a high share of coal utilization, however, is presently considered to be environmentally undesirable, unless less polluting coal technology and mitigative techniques are utilized. This will require higher investment costs, while capital availability is highly constrained.

(iii) Conservation measures in the power sector are, therefore, essential and need to be pursued, and there is considerable potential for that. The present total loss in the transmission and distribution only is still relatively high, i.e., within the range of 23 to 26%. Furthermore, DSM has not been practised. It will be initiated in 1993. Efficiency improvement of the power sector is also desired in terms of fuel conservation and from the environmental point of view.

(iv) As one of the many means of achieving improved efficiency, this study has focused on the potentials of wider application of cogeneration technology. While the technology is not entirely unknown in the country, it is observed that there is considerable degree of lack of familiarity and appreciation.

(v) An initial analysis of the opportunity for augmenting cogeneration to existing power generating systems in the industrial, commercial, and power sectors indicates that there is around 6675 MW potential capacity for cogeneration application in 1990, i.e., 445 MW in the combined heat power cogeneration and 6230 MW in the diesel combined cycle mode. If and when the latter was utilized, PLN would have an opportunity to acquire an additional supply capacity of around 4650 MW. Of this capacity, 2775 MW is due to the supply of captive plants in new industrial estates and the operation of stand-by captive power units at the industrial and commercial sectors. The balance is additional capacity that would be created from the application of cogeneration technology at PLN's diesel plants and the above mentioned captive units. If and when both heat power cogeneration and diesel combined cycle potential were fully utilized and assuming that the corresponding demand would otherwise be supplied by using diesel fuelled steam boilers and conventional diesel power generators, emissions of 8.4 million tonnes of CO_2 per year could have been avoided. This avoidable CO_2 emissions potential accounts for around 6.5% of total CO_2 emissions from the Indonesian energy sector, which was estimated at about 130 million tonnes per year in 1990.

(vi) The observations pointed out in points (iv) and (v) imply that there is a need for technology transfer processes to be undertaken, and further study on the economic justification and feasibility for undertaking the transfer process through investment channels is warranted.

(vii) Assessing the domestic capability and capacity in engineering design and equipment manufacturing, the study suggests that the transfer process is best undertaken by focusing first on the development of cogeneration system's design capability and the manufacturing of the station-

ary components of the cogeneration system such as efficient heat exchangers and waste heat boilers. The manufacturing of rotating equipment can be considered at later stages. Until such undertaking is considered justifiable, rotating equipment and instrumentation devices are components that have to be imported. It must be noted that the requirement for rotating equipment arises only when a combined cycle system is to be delivered.

(viii) Private power generation schemes, through which cogeneration systems, in some cases, are implemented, has been officially introduced through the issuance of the Private Power Generation Regulation. However, the specific and detailed guidelines required for implementation of the regulation still have to be prepared.

(ix) It must be pointed out that some advocacy initiatives are necessary to develop a more conducive environment for the wider functioning of cogeneration systems, whereby the support of donor agencies may considerably help in accelerating such efforts.

On the basis of the above conclusions, particularly points v–ix, it is recommended that further study be made focusing on the assessment of the market potential for implementing cogeneration systems, and based on that, produce a set of proposed investment schemes for the realization of commercially operated cogeneration delivery systems, and the commercial application of cogeneration systems based on externally acquired and the best available technology. Furthermore, considering that similar potentials are found in many Asian countries, it is also recommended that mobilization of some funding resources be made to support the organization of region-wide workshops and seminars, focusing on the technical and techno-economic aspects of the technology.

ANNEXURE I

Business environment

Loans for investments
The procedure to get loans for investments is relatively simple. The application for investment loans has to be submitted with a feasibility study. If credit is to be included in the existing special programmes, then the fixed procedures and criteria have to be followed.

A specific financial scheme exists for each of the credit programme categories. With deregulation or policy reforms, the number of these special credit programmers has reduced considerably. Each bank has its own procedure and criteria; the normal four considerations applied are, character of the management, capability, capacity to earn profit, and capital.

With the recent developments, banks can accept projects if it considers them safe in terms of risks. There are also cases where several banks establish a consortium to finance an investment if:

- the amount of credit is too large to be handled by a single bank;
- the amount of credit exceeds the legal lending limit; and
- the bank does not have sufficient knowledge and experience to finance a certain business.

The facility to finance long term investments is widely absent. Accordingly, many banks hesitate to give long term credit even on a high interest rate. The depositors are also reluctant to deposit money for a long time. This is mainly the equity share holding structure of some banks.

Changes in interest rate
Since the launching of the deregulation package dated 1 June 1983, banks have more freedom in setting the interest rates of money deposits as well as loans. The launching of the policy package dated 30 October 1988 was partially aimed at controlling the tendency and seems to have had positive effects in stabilizing the interest rate level.

In the effort to control inflation rate, the government launched a tight money policy towards the end of 1990 and increased the interest rate on loans to 24–28%. The continuing high interest rate has apparently had undesired effect on the business world; the banks have responded to such a development by taking joint initiatives to bring down the interest rate to lower levels. The current level of interest rate is around 22–23% per annum.

Forms of business organizations
There are four major types of business organizations—(a) basic partnership, (b) open partnership, (c) limited partnership, and (d) limited liability company. Basic partnership (*maatshap*) is usually opted for by lawyers, accountants, and other similar professionals. This type of business form can be established without formal filing or government approval. Open partnership (*firma*) is usually established for small trading or service enterprises. The deed of establishment of this type of business must be

drawn up by a notary. Limited partnership is basically similar to open partnership, but involves mostly family enterprises. The limited liability company, *Perseroan Terbatas* (PT), is commonly opted by large enterprises, although size is not a requirement for eligibility. The deed of establishment must be in notarial form, approved by the Ministry of Justice, registered at the relevant local court, and is published in the state gazette. PT is the most appropriate form for modern business ventures.

The salient features of the above business forms are listed below.

Basic partnership:

- assets can be held separately by the partnership;
- restricted authority of one partner to bind other partners;
- joint liability of partners for equal parts only;
- no several liability of partners; and
- unlimited liability of partners.

Open partnership:

- assets can be held separately by the partners;
- partners can bind the partnership to third parties;
- joint and several liability of partners; and
- unlimited liability of partners.

Limited partnership:

- assets can be held separately by the partners;
- silent partner contributes capital and liability is limited to the amount of such contribution;
- silent partner may not participate in the management;
- management rests with active partners; and
- active partners have unlimited liability.

The essential features of PT are as follows:

- it is a corporate entity having shares with limited liability of shareholders;
- it is managed by a Board of Directors (mandatory) which is supervised by a Board of Supervisors (not mandatory). The Board of Directors and the Board of Supervisors are responsible to the General Meeting of Shareholders;
- at least 2 founders are required;
- joint and several liability of founders exists until the Deed of Establishment has been approved the Minister of Justice; and
- joint and several liability of Directors exists until the approved Deed of Establishment is registered with the relevant local court and published in the State Gazette.

Foreign investment
The basic legislation on foreign investment in Indonesia is based on Law no. 1/1967, and later amended by Law no. 11/1970. In these laws, foreign capital is defined as foreign exchange which are not forming assets or part of assets not procured with Indonesian foreign exchange reserves, and also reinvested profits which are free to be repatriated. Administration and approval of foreign capital investment in the majority of economic sector excluding oil, gas, and other mining sectors, finance and insurance, is governed by BKPM.

As a general rule, the minimum total intended investment is set at one million US dollars, with the exception that a sum as low as US $250 000 is allowed for investment in sectors requiring less capital. Labour intensive and export oriented projects which support the large-scale industry, and projects entirely aimed at exports were declared as privileged projects.

Foreign joint venture company (the PMA Company)
In general, the stipulated form for foreign investment, known as the PMA Company, is a joint venture with an Indonesian partner in the form of a PT. Basic features of PMA company include:

- only approved activities can be undertaken;
- usually not permitted to be involved in retail trading;
- maximum initial shareholding is 80%, moving to minority within 15 years; in exceptional circumstances (i.e., more than 65% of product is for export), the initial shareholding may be 95%, to be reduced to 80% within 10 years, and 49% within 15 years;
- minimum investment is US$ 250 000 comprising loan and equity capital. Often at least US $1 million will be required in manufacturing sector;
- facilities for import duties, value-added tax (VAT) on purchase of capital goods and funds repatriation are available.

Where investment is located in bonded areas and the product is 100% for export, a maximum of 95% foreign shares is also allowable.

Other forms of foreign business participation
Foreign capital can, other than in PMA companies, be used for business in Indonesia through:

- appointment of agents and/or distributors;
- joint operations or co-operation agreements;
- opening representative offices; and
- technical or financial assistance agreements, licensing agreements, etc.

Investment in this category includes business in oil and gas, general mining, forestry, and finance, and banking.

Taxation

The present tax laws of Indonesia include Law no. 6/1983 on general tax provisions and procedures; Law no. 7/1983 on income tax, applicable to individuals and organizations; and Law no. 8/1983 on VAT on goods and services, and sales tax on luxury goods, applied to business.

The tax system is basically a self-assessment system with extensive withholding of tax provisions. Tax authorities do not issue clearances unless adjustment in the form of tax assessment or tax collection notices are made resulting from any tax audit within a period of five years from the date the payment is due. The general features of the income tax law are as follows:

- tax subject to the income tax law;
- resident tax subject and non-resident tax subject; and
- tax object is the world-wide income.

The taxable income of an organization or individual is arrived at by subtracting permissible deductions and non-taxable income from the gross income. The permitted deductions include:

- the cost of deriving, recovering, and conserving;
- losses which may, in most cases, be carried forward for five years; and
- depreciation of the acquisition cost of property and amortization of costs incurred in obtaining rights and other costs that have a useful life of more than one year.

A permanent establishment is subject to tax on taxable income rates above 20% on the after-tax taxable income, subject to the existing Double Tax Agreement (DTA).

The DTA generally provides for the avoidance of incidental double tax on certain incomes like profits, dividends, interests, and royalties, because they are derived from one DTA country and remitted to another. The existing DTAs follow international models for such agreements. Presently Indonesia has concluded DTAs with the following countries: Netherlands, Canada; Austria; Belgium; Philippines; India; Great Britain; Thailand; New Zealand; Germany; Japan; France; and Denmark.

VAT is imposed on the rendering of services, imports, manufactured goods, and all traded goods, excluding retail, at a rate of 10%. Luxury sales tax is only imposed once on a wide range of luxury goods at the manufacturing or import level at rates of 10, 20, and 30%.

ANNEXURE II

Technological level of power generator system components

Equipment	Local product	Imports product
Hydroturbines	—	✓
Hydrogenerators	—	✓
Gas turbines	—	✓
Steam turbine generators	—	✓
Boilers	✓	—
Diesel generators	✓	—
Reinforcing steel	✓	—
Structural steel (sections)	✓	—
Structural steel (building)	✓	—
Water tanks	✓	—
Chain link fencing	✓	—
R Concentrate piles	✓	—
P Concentrate piles	✓	—
Water stops	✓	—
Fire hydrants	✓	—
Fire piping	✓	—
Fabricated welded pipes	✓	—
PC Circulation, Water pipes	✓	—
FRC Pipes	✓	—
DVC Pipes	✓	—
Roofing material	✓	—
Penststocks	✓	—
Gates	✓	—
Steel stacks	✓	—
Ducts	✓	—
High pressure piping	—	✓
Low pressure piping	✓	—
Instrumentation tubes	✓	—
High pressure valves (large size)	—	✓
High pressure valves (small size)	✓	—
High pressure heat exchangers	—	✓
Circulating water pump	—	✓
Small pumps	—	✓
Medium size pumps	—	✓
Boiler-feed pumps	—	✓
Boiler-feed pumps	—	✓
Conveyors	✓	—
Cranes	✓	—
Hoists	✓	—
Hoppers	✓	—
Electrical Cables	✓	—
Cable trays	✓	—
Main transformers	—	✓
Other transformers	✓	—
Switchgears	—	✓
Control boards	✓	—
Feed water treatment plants	✓	—
Batteries	✓	—
Storage tanks	✓	—

Japan's technology transfer policy and problems in future

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1 Official development assistance and technical co-operation

Japan's actual extension of official development assistance (ODA) in 1991 reached $10 951 million, against 9069 million registered in 1990. This was the largest amount among the Development Assistance Committee (DAC) member countries, followed by $9642 million donated by the US and $6769 million by Germany. Japan's ODA included technical co-operation, which rose from $1645 million in 1990 to $1868 million in 1991—a 16.9% increase.

Although Japan's ODA tops the world in gross volume, it represents a mere 0.32% of the gross national product (GNP)—slightly lower than the 20 DAC member countries' average of 0.34%—and is ranked 12th. Given the rising expectations and requests by the rest of the world for Japan's assistance and with the emergence of global environmental problems, Japan is being urged to increase the ratio of its ODA *vis-a-vis* GNP in the future. By way of comparisons, the US's ODA represents only 0.17% of GNP, ranked 20th, while Germany's ODA represents 0.4% of GNP—ranked 9th. It is therefore, the major ODA donors' common obligation to raise the ODA–GNP ratio. This paper outlines the current status of Japan's technology transfer policy, focusing on its technical co-operation, and an analysis of the related problems in the future.

2 The current status of Japan's technical co-operation

Japan's technical co-operation takes various forms. There is the project-type technical co-operation, which combines the acceptance of trainees, the dispatch of experts, and the provision of equipment. Others include development studies and the dispatch of Japan Overseas Co-operation Volunteers (JOCV). Technical co-operation activities supported by public funds include the acceptance of students from the developing countries at government expense, and survey and research programmes conducted by government affiliated agencies and other organizations in co-operation with government agencies in the developing countries.

As is the case for total ODA, Japan allocates a large share of its technical assistance to Asia. A regional analysis of technical assistance provided in 1990 shows that Asia received 49.08%, Latin America 12.1%, Africa 7.6%, the Middle East 5.8%, the Pacific 1.9%, and Europe 1.0%. The current status of technical co-operation by major programmes is outlined below.

2.1 Technical training programme

Japan launched the technical training programme in the fiscal year (FY) 1954 and received a cumulative total of 82 553 participants in the programme by the end of March 1991. It received 5183 participants in the FY 1990. The technical training programme includes group, individual, and third country training, and the establishment and operation of training centres. In addition, Japan is providing 'follow-up service for ex-participants', sending abroad 13 teams of experts to acquaint ex-participants with new technologies and give technical advice adapted to local conditions.

2.2 Expert dispatch programme

Japan dispatched a total of 14 501 technical experts overseas during the period 1955–1990, sending 1592 experts in 1990. This programme covers joint study projects, aimed at contributing to socio-economic development of recipient countries, dispatch of private sector skilled workers, and sending of survey teams.

2.3 Provision of equipment

Japan's provision of equipment necessary for promotion of technical co-operation began in 1964, having reached a cumulative total of ¥21 billion by 1990. In 1990, equipment worth ¥7000 million was provided to 50 countries.

2.4 Project-type technical co-operation

Project-type technical co-operation is a programme in which three forms of co-operation are combined into one—training of overseas participants, dispatch of experts, and provision of equipment. Project-type technical co-operation implemented in 1990 involved 185 projects, including those completed within the FY. Of these, 57 were social development co-operation projects, 35 health and medical, 8 population and family planning, 66 agriculture, forestry, and fisheries, and 19 in industrial development co-operation. By regions, 106 were carried out in Asia, 17 in the Middle East, 18 in Africa, 41 in Latin America, two in Oceania, and one in Europe.

2.5 Development studies

Development study is the general term that involves the following activities carried out for public development planning, which is necessary for the socio-economic progress of developing countries: (i) organizing study teams composed of experts to contribute to the implementation of a development plan for the recipient country; (ii) carrying out a field survey, as well as analysis and study in Japan

of the findings of the field survey; (iii) making a study report which serves as basic information on a socio-economic development strategy for the recipient country; and (iv) promoting technical transfer in terms of study methods and a planning approach to local counterparts in the course of the development study.

Development studies are classified into the following categories—master plan studies, feasibility studies, detailed design studies, and studies for improving project efficiency. In 1990, 275 development studies were carried out—182 were funded from the budgetary item for development studies, 74 from that of overseas development planning studies, and 19 from that of resource development co-operation basic studies. 152 development studies were conducted in Asia, 25 in the Middle East, 35 in Africa, 54 in Latin America, 5 in Oceania, and 4 in Europe.

3 Energy co-operation

3.1 Current status of co-operation in the energy sector

Compared with other advanced countries, Japan devotes a high proportion of its ODA to the energy sector. Table 1 examines the bilateral ODA in the energy sector. Over the past five FYs (1986–1990), this area has accounted for approximately 15% of total financial assistance. However, an analysis of past trends shows that assistance in this field has declined from the FY 1983 peak of ¥230.9 billion (32.6 % of total assistance). In 1989 and 1990, the energy sector accounted for only about 12% of total financial assistance. This strong emphasis on energy reflects Japan's active co-operation in this field, which it regards as one of the most important areas of assistance in the light of energy develop-

Table 1. Bilateral ODA in energy sector (commitment basis)

FY	Grant aid (100 Million ¥)	ODA Loans (100 Million ¥)	Trainees accepted	Experts dispatched	JOCV
1986	56.09	1120.78	155	22	0
	(5.4)	(20.0)	(2.6)	(1.1)	(0.0)
1987	28.09	1873.94	186	18	5
	(2.6)	(26.9)	(2.9)	(0.8)	(0.6)
1988	28.91	1564.23	196	49	2
	(3.0)	(14.7)	(2.9)	(2.0)	(0.6)
1989	45.52	1518.99	238	33	2
	(4.3)	(15.5)	(3.2)	(1.4)	(0.2)
1990	9.63	1057.83	211	22	0
	(1.0)	(10.5)	(2.8)	(0.9)	(0.0)

Note. Figures in parentheses are respective shares in general grant aid (excluding grant aid for debt relief, non-profit grant assistance, and small scale grant assistance), ODA loans (excluding reschedule), and technical co-operation.

ment as a key input for industrial development. Projects in the energy sector have the potential to produce profits. For this reason, financial assistance is provided primarily in the form of loans. Over the past five years, loans have accounted for 98% of total financial assistance in this area.

In the case of Indonesia, for example, Japan has provided aid for projects, e.g., for setting up a hydro-electric power station on the Brantas River in Eastern Java, and thermal power stations at Gresik and Surabaya. The power generation capacity created through this assistance now accounts for 31% of Indonesia's total capacity, and Japan's co-operation in this area has made a major contribution to Indonesia's economic and social development. In Laos, Japan provided aid for a hydro-electric scheme, the Nam-Gum Dam. The output of this scheme is so large that Laos is able to earn foreign currency by supplying some of this electric power to Thailand.

Co-operation in the field of energy involves such areas as energy resource development, power generation and transmission facilities, regional electrification, the development of new energy forms, energy conservation, and energy administration. Electric power generation projects are by far the largest category, but in recent years there has also been an increase in the number of regional and rural electrification projects.

3.2 Priorities for co-operation in the energy sector

3.2.1 Integration of economic planning and energy planning

It is important to incorporate energy planning into the economic plans of developing countries, and to provide assistance in ways that reflect medium and long range policies relating to energy supply and demand and the development of energy. When formulating energy plans, it is first necessary to prepare development and utilization plans that permit the achievement of the optimal energy mix, taking into account such factors as the extent of energy resources, geographical conditions, the structure of the industry, economic growth rates, energy demand patterns, and population distribution.

Co-operation at the 'software' level, including human resource development, the improvement of administration capabilities, and the establishment of the necessary legislation, is effective in relation to the drafting of these plans, and, in this sense, it will be necessary to enhance Japan's response at the level of technical co-operation. Human resource development and technology transfer are also vital to the operation and maintenance of energy facilities, as well as to the collection and analysis of energy related data. Technical co-operation is also important from this point of view.

3.2.2 Correcting imbalances between urban and rural sectors

Rural electrification leads to improvements in rural living standards and is therefore essential to eliminate gaps between the urban and rural sectors. However, there are a number of problems, including the limited profitability of electric power services in the rural sector of developing countries, and the fact that small scale power generation for rural and regional electrification is more costly than large scale generation. For this reason, assistance for rural and regional electrification should be provided primarily through grant aid.

Rural communities in developing countries use trees cut from nearby forests to provide domestic fuel in the form of firewood and charcoal. As a consequence of population growth, many areas, such as Nepal and the Sahel region of sub-Saharan Africa, now face serious fuel shortages and environmental problems due to the depletion of forests through excessive logging. In addition to the small scale power generation mentioned above, other approaches should also be considered, including the use of alternative energy resources such as dung, straw, briquettes, and the popularization of efficient ovens.

3.2.3 Environmental considerations

Gases emitted by hydrocarbonate thermal power stations cause atmospheric. This can be prevented through the improvement of plant management technology and the use of desulphurization and dust collection systems. Japan possesses advanced technology in the field of pollution control and will need to make an active contribution through technical co-operation in this area. Since the high cost of these facilities would impose a considerable burden on developing countries, it will probably be most effective to co-operate in the development of simplified systems that suit conditions in these countries.

3.2.4 Joint financing with the private sector

Many developing countries have difficulties in developing their energy resources efficiently because of their limited financial resources for investment in the energy sector. Some large-scale electric power projects cannot be financed solely through ODA, and consideration should therefore be given to promote joint financing with private sector investors, in cases where the prospects for the recovery of funds are good.

4 Measures to be taken to implement Japan's technology transfer policy

4.1 Comprehensive and integrated structure of technology transfer

Outlined above is the current status of Japan's technology transfer policy, focusing attention on government supported technical co-operation, which is comprehensive and integrated in its structure. Let us now consider technology transfer of, for example, a most advanced 600–1000 MW coal-fired power generation plant (having a thermal efficiency of 39%), with highly efficient flue gas desulphurization equipment.

First of all, it is necessary to consider the transfer of technology for assembling and installing a generator and related facilities. (Transfer of technology related to production of these equipment and facilities is not considered here.) Next, the transfer of the related technical know-how to management, technical personnel, and labourers is undertaken, assuming that all of them are available to manage, operate, and carry out maintenance of the power plant in question. Then, supply of fuel and spare parts for maintenance must be secured. Moreover, an efficient network must be established for transmission, sales, and distribution of the electric power that is generated. It is necessary that the project in question be well incorporated in the power generation plans as well as the energy plans of the state

and regional area concerned. Of course, it is essential that adequate funds, necessary to implement technology transfer, and technical expertise be dispatched from the donor country to recipient countries.

Technology transfer through the establishment of a joint venture company is being carried out fairly smoothly in areas where these conditions are met, since the project is placed on a commercial basis. Generally speaking, however, the larger the project becomes, the greater is the support required from both the governments in the form of preferential measures needed in order to place the project on a paying basis. If the construction and management of the coal-fired power plants referred to above, for example, is implemented under the build, operation, and transfer formula, in which developing countries are showing keen interest, the foregoing conditions must all be met. At the same time, difficult problems like the establishment of power rate, assurance of the profitability of the project, and repayment terms for borrowed foreign capital must be resolved. Government support through powerful preferential measures is indispensable for the successful implementation of technology transfer, but there must be some limitations to this governmental support. It should be pointed out that, in the end, self-help efforts, on the part of the recipient countries, must be the trump card.

4.2 Establishment of a priority order and the importance of project finding

In order to successfully promote technology transfer, which is beset with a number of problems as outlined above, it is essential to establish an order of priorities and find a most appropriate project. In establishing these priorities for projects, it is important to pay due consideration and give top priority to those given below.

(i) The technology that best fits the current conditions of recipient countries (especially the socio-economic realities and the people's life-styles).

(ii) The technology that meets the foregoing conditions and has a high cost-effectiveness.

(iii) The technology that can offer multi-purpose solutions to serious problems now facing developing countries, such as the gap in economic development between urban and rural areas, damage to forests, traffic congestion, air pollution, trade deficits, and so on.

(iv) Given the above conditions, state-of-the-art technology is not necessarily essential. It is more important to find a technology, which may be at the infant or intermediate level and, yet, have a high cost-effectiveness.

(v) Essential projects must cover a wide variety, ranging from the use of the 'konro' (a portable cooking stove) and the 'kamado' (an oven), improvement in thermal efficiency of boilers in a small scale factory, coal washing, and electric dust collecting, to technologies of simplified desulphurization and fluidized bed combustion. This would help reduce air pollution and conserve energy and indirectly reduce CO_2 emissions.

4.3 Measures for overcoming problems in Japan

Drastic expansion of energy and environment related ODA budgets and flexible appropriations, governmental support of R & D studies in Japan on technologies suitable for developing countries,

preferential measures applied to capital investments by joint venture companies in desulphurization, and energy conservation facilities must be looked into. There is also the need for re-examination of the current formula of Japan's accepting requests from recipient countries, strengthened project finding activities, and expansion of research and bilateral/multilateral meetings.

Rapid expansion of training programmes for the technical experts from the recipient countries needs to be carried out. This includes expansion of the number of Japanese experts dispatched to recipient countries, education of talented personnel to provide such experts, and improvement in their salaries. Efforts must be made to eliminate language barriers among those engaged in these activities. (In general, utmost efforts must be made to overcome the absolute shortage of human resources undertaking Japan's technology transfer.) Promotion of co-operation to formulate energy master plans has also to be undertaken and plans for technology transfer mooted which would then provide a basis for successful technology transfer.

4.4 Measures for overcoming problems in recipient countries

Solutions for the various problems arising out of technology transfer in recipient countries would require the measures outlined below.

(i) Formulation of pertinent, realistic, and detailed energy and technology transfer plans, commensurate with economic plans; and the establishment of a system for implementation and management of those plans, with the necessary expansion of the data and statistics required to support them.

(ii) Education of technical personnel undertaking the technology transfer and its maintenance, and efforts to produce related equipment/facilities and spare parts in recipient countries themselves.

(iii) Establishment of the 'road to sustainable development' which best fits the culture and climate of the recipient countries, proposals for technology transfer plans suitable with their culture and climate, and measures to implement these plans.

(iv) Expansion of the government's preferential measures for technology transfer from foreign countries, including joint venture companies.

5 Conclusion

Technology transfer is a joint project between donors and recipients aiming at global 'sustainable development' and common benefit. To make it a success, it is essential that a comprehensive and integrated structure, involving the various conditions outlined above, be firmly established, or at least that, both parties spare no efforts to establish that structure. Otherwise, even if Japan increases energy and environment related budgets, actual projects will not be implemented in an appropriate manner—a situation that would be distressing to both parties.

The role of technology transfer in abating CO_2 emissions: the case of the Republic of Korea

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1 Introduction

This study provides a Korean experience of technology transfer, particularly in electricity technology, with the expectation that Korean patterns and mechanisms for technology transfer might be used as a reference for other developing countries, in the efficient transfer of environmentally sound technologies (ESTs). The indigenization of foreign technology in Korea[1] has been carried out with a partnership model in which the state, public corporations, R & D institutes, and industrial conglomerates were systematically integrated for technology transfer.

While Korea was successful in the indigenization of foreign technology through an institutional alliance, it has not succeeded as well as transfer of ESTs because of the lack of a coherent domestic policy, and a competitive global economy. In the study, cogeneration technology is analysed as a recent case of technology transfer in Korea together with its relation to the domestic energy requirement and global industry. In order to facilitate the transfer of ESTs, the study suggests 'three stages of technology transfer' and 'five strategic stages of capacity building'. It also presents the problems of dynamic conservatism like concentrated domestic institutions and global dominance of technically advanced countries in transferring ESTs.

2 Indigenization of technique through technology transfer

2.1 Introduction

This study explains the role of technology transfer in abating CO_2 emissions in Korea. Through an investigation of technology development in the general and the power sector, and cogeneration in particular, the analysis explains how Korea indigenized foreign technologies, the kinds of technology related institutions that were developed, and finally seeks to develop mechanisms for technology transfer in the future.

[1] Hereafter, the Republic of Korea is referred to as Korea.

Since the Uruguay round of talks and the Rio convention, technology transfer between developed and developing countries has emerged as an important issue with an emphasis on the distribution of resources and capital. The Korean experience of technology transfer, particularly in the power sector, will be of considerable use in investigating patterns and mechanisms for technology transfer. This could be used as a reference for the efficient transfer of environmentally sound and energy efficient techniques among countries.

Technological development in developing countries usually starts with the import of advanced foreign technology and proceeds through the development of technology-related institutions to the final stage of technological self-reliance. The experiences of many less developed countries (LDCs) suggest that little can be expected from technology transfer in the absence of an institutional capacity to indigenize it. Therefore complementary efforts are necessary to indigenize foreign technology to achieve viable results from technology transfer.

The indigenization of foreign technology in Korea has been carried out with a partnership model in which the state, public corporations, R & D institutes, and industrial conglomerates were integrated for technology transfer. During the 1960s and 1970s, the country tried to increase its absorptive science and technology (S & T) infrastructure by expanding and improving S & T institutions and education, on one hand, and by acquiring foreign technology on the other. By the early 1980s, the need for rationalization of S & T development with economic development became evident. In order to upgrade the domestic industrial structure and reduce dependence on the technology of industrialized countries, Korea strengthened the existing alliance of institutions, creating a highly concentrated technological system. Rapid change during the 1980s in industrial technologies led conglomerates (called *chaebols*) to establish and expand their own research institutes. These private research institutes formed a new type of linkage among industries, public institutes, and universities. Investment in S & T came mostly from the government prior to the early 1980s, but the situation is changing now. Corporations are seeking to internalize technological innovation and technology transfer to avoid potentially disruptive effects of new developments, and to target research efforts better.

While the case of Korea is one of successful transfer of technology for the transformation of an agrarian economy to an industrial one within four decades, inadequate attention to social impact has actually left the country with a highly concentrated institutional framework leading, in turn, to environmental degradation. These rigid institutions under uncertain conditions find it difficult to cope with the rapidly changing global economy, the increasing demand for environmental preservation, and the political and economic localization in the nation. Another important impact of the prevailing involvement of concentrated private conglomerates in technology transfer and development is the redirection of research and efforts away from the basic concerns such as ESTs and towards shorter term commercial possibilities (Kim 1991).

The Korean experience of technology transfer in the power sector manifests general patterns of technology transfer and its relation to institutional development. Korea has managed to develop, over the last four decades, a well-functioning power system, simultaneously building up considerable

skilled manpower in the area of power plant operation, engineering, and construction. Since the mid-1970s, the country has implemented a policy for indigenizing the sources of supply for power plant engineering services and equipment. This indigenization policy has been carried out with an integrated development of the public utilities, domestic machinery producers, and the state. Through the combined efforts of a single public utility—the Korea Electric Power Corporation (KEPCO)—and related conglomerates and public institutions, Korea has achieved rapid transfer of foreign technologies into the power sector. With the pursuit of nuclear power, centralized power institutions already in place were strengthened to continue the transfer of more advanced technologies. The monopolistic arrangement of power related institutions and construction and equipment manufacturers were successful in technology transfer. However, this is now so pervasive that these institutions (e.g., KEPCO) have become institutional barriers in transferring environmentally sound and energy efficient technologies, such as small and medium scale cogeneration power plants.

Korea's efforts to resolve the conflict between efficient technology transfer and centralized institutional organization will provide an excellent context for a study on sustainable development which tries to harmonize economic and technological development and environmental preservation. More details on Korea's experience in technology transfer, especially in the power sector, are provided in the sections to follow.

2.2 Three stages of technology transfer

Tables 1 and 2 outline the patterns and stages of technology transfer in Korea, showing their linkages to economic and institutional development. In the first stage, which covers the 1960s, industry was

Table 1. Stages of technology transfer and development

Pattern	Stage 1 (1960s)	Stage 2 (1970s)	Stage 3 (1980s)
Form of technology transfer	'Packaged' turnkey technology	'Semi-packaged' technology. Participation of local firms	'Unpackaged' technology. Indigenous efforts
Emphasis on technical tasks	Implementation of imported technologies	Facilitation for the adaptation to imported technologies	Improvement for enhancing competitiveness
Critical technicians	Foreign experts	Local technicians and foreign experts	Local scientists and engineers
Local R & D institutions	Consultative	Adaptive development	R & D
Emphasis on economic turnkey projects	Import substitution and oriented export light industries	Export. Heavy and chemical industries	Quality of export goods and export of technology-intensive goods

based on simple skilled labour, paving the way for the development of basic industries such as energy, fertilizer, and cement for import substitution as well as for the expansion of export oriented light industries. For such industrial demands, foreign technologies were introduced under a licensing agreement. Local institutional capabilities were so weak that most foreign technologies were imported as turnkey types embodied with capital goods, rather than as patent rights.

The Korean government created technology related institutions while facilitating the adoption of imported technology. The Economic Planning Board (EPB) and the Ministry of Science and Technology (MOST) were established for the economic policies and S & T related policies respectively. MOST has initiated the establishment of R & D organizations to cultivate technical manpower and international co-operation. MOST also played an important role in creating laws such as the Foreign Capital Inducement Law and the Law for Advancement of Science and Technology. The Korea Institute of Science and Technology (KIST), the first modern multi-disciplinary research institute in Korea, was established with activities ranging from project feasibility studies and technical services, to engineering studies on a pilot plan scale.

Since the mid-1960s, the Korean scientists and engineers who have studied or trained abroad have been actively sought and repatriated with various kinds of support from the government. They have been recruited by research institutes, colleges, and industries. Parallel to the strengthening of technical education, informal education and job training were also institutionalized. The adoption of improved technology and the establishment of related institutions were the major features of the first stage of technology development in Korea.

The second stage in the 1970s can be categorized as the full establishment of institutional framework for the transfer of western technologies. In addition to the two primary institutions of MOST and KIST, many other institutions were founded and corporations for the implementation of technology transfer were intensively established. The accumulation of technical experience throughout the 1960s provided a base for local industry to move on to the next stage of technical development, i.e., the assimilation of foreign technologies. In order to facilitate technology transfer, the government encouraged a select group of industries and corporations, including machinery, metals, chemicals, ship building, and electronics. On the other hand, a dozen other government-supported research institutes were also established which specialized in the above areas.

College and graduate education was rapidly expanded during this period with special emphasis on mechanical, chemical, and electronic engineering. In particular, a new graduate school—Korea Advanced Institute of Science (KAIS)—was established. In order to foster domestic engineering capabilities, the government enacted the Engineering Service Promotion Law, particularly for small firms. By offering tax incentives, small engineering firms have been encouraged to integrate and specialize. Joint engineering service firms and plant exporting companies have also been encouraged to acquire knowledge and experience from their foreign counterparts. Efforts have been made to improve import and existing technologies while continuing to enhance problem solving capabilities through such means as education and training.

Table 2. Stages of institutional development

Institution	Stage 1 (1960s)	Stage 2 (1970s)	Stage 3 (1980s)
Government	EPB; MOST	National Council for Science and Technology; Korea Technology Advancement Corporation	Korea Technology Development Corporation; Korea Development Investment Corporation; Korea Technology Finance Corporation
R & D institute	KIST	KAIS; Korea Scientific and Technical Information Center	KAIST
Legal system	Foreign Capital Inducement Law; Law for Advancement of Science and Technology	Law for Industrial Technology Promotion; Engineering Service Promotion Law; National Technical Qualification Law; Law for the Development of Specially Designated Research Institutes	Provision of previous laws
Education (strength of technical education in formal education)	National Central Vocational Training Institute; Assistance of International Bank for Reconstruction and Development, International Labour Organization, etc.	Vocational junior college education; compulsory in-plant training system; Vocational Training Deliberation Committee; Chang-won Industrial Masters College	Korean Vocational Training and Management Agency; Vocational Training Research Institute

In addition to the expansion of education and training, many public corporations like the Korea Technology Development Corporation (KTDC) were established to provide financial support for the development of new technologies, products, and processes. KTDC was mandated to induce the development of high technology related industries by providing venture capital to private enterprises.

In the 1980s, the government and R & D institutes were merged into 'Big Science' agencies, in which science, industry, and the government began to combine and institutionalize their S & T efforts (Seidel 1986). The scaling up of technological interests of the state coincided with the government's effort to improve the effectiveness of technology development and further consolidate the institutional organization of Korea's technology development.

Many R & D institutions were reorganized. For example, KIST and KAIS were merged into the Korea Advanced Institute of Science and Technology (KAIST). In addition, 16 state supported research institutes were consolidated into nine—Advanced Energy Research, Electric Technology and Telecommunications, Standard Research, Ginseng and Tobacco Research, Energy and Resources, Machinery and Metals, Electronics Technology, and Chemical Technology.

The environment for technology development in the 1980s had undergone a rapid change, both at home and abroad, making it entirely different from that of the past two decades. As the industrial structure shifted from being a labour intensive to a technology intensive one, industries had begun to require more sophisticated and higher technology than before. Importing advanced technology was no longer an easy task because of the trends of protectionism and the high costs of technology transfer. A virtually independent capacity for technological development in the area of light industry, and a limited dependence on foreign technology in the heavy and chemical industry, were the characteristics of the third stage of technological development in the 1980s.

2.3 Current status of technology transfer

2.3.1 Introduction

As a result of continuous efforts for three decades, Korea is, as a whole, approaching the level of the advanced nations in the areas of assembling and processing technologies. However it is still very weak in core industrial technologies such as design, materials, and software. Despite the progress in technological development, the level of productivity and competitiveness among Korean firms and industries has decreased relatively when compared to the global level, resulting in the reversal of trade surplus since 1988.

It has been observed that developed countries have become increasingly more reluctant to transfer their advanced technology to developing countries. This is due to the fear of self-defeat in the international trade market by the transfer of technology, which is called the 'boomerang effect'. Mutual benefits of technology transfer were largely devalued. Korea is one good example of the widening domestic market for the exporters of the advanced countries, especially for Japan and the US. In 1961, the Korean market open to international exporters was worth only 40 million dollars, which led to its being sidelined in world business. Rapid industrialization provided 80 billion dollars of domestic market to the advanced countries by 1991. Past experience reveals that in newly industrialized countries technology transfer has accelerated the process of industrial development which, in turn, has expanded the export market for developed countries. Korea's economy increased domestic imports from Japan from 10 million dollars in 1961 to 25 billion dollars. This experience shows that technology transfer has accelerated the process of industrial development in developing countries, leading to a corresponding increase in the exports and imports markets at the same time.

Korea still depends heavily on foreign technology (Table 3). In 1988, Korea's dependence on foreign technology was 21.1% while that of the US, Japan, Germany, UK, and France was 1.1, 6.1, 5.9, 9, and 6.2% respectively. This indicates that technology transfer is still essential for the development of technology levels in Korea.

2.3.2 Technology import and export

From 1962 till the end of 1991, Korea has registered more than 7500 cases of technology transfer which have greatly contributed to its advancement in the technology level. However, the number of

Table 3. Dependence on foreign technology (%)[a]

Year	Korea	US	Japan	Germany	UK	France
1987	22.1	2.6	0.6	6.3	7.1	7.5
1988	21.1	1.1	6.1	5.9	7.0	6.2

[a] Value of technology imports/R & D investment
Source. Ministry of Trade and Industry, Government of South Korea

technology transfers began to decline after it peaked in 1989 due to the recent trend of protectionism. In 1990, the case of technology import had decreased to 3.3% compared to the previous year. On the other hand, the amount of royalty payment is on the rise, along with the strengthening of protection of intellectual property rights (IPRs), and an increasing need for higher technology. In 1990, there was a 22.3% increase in total royalty payments compared to the previous year (Figure 1).

In 1990, the cases of imported technology from the US and Japan were 221 and 333 respectively, amounting to 574 and 341 million dollars correspondingly. This led to Korea's high dependence on

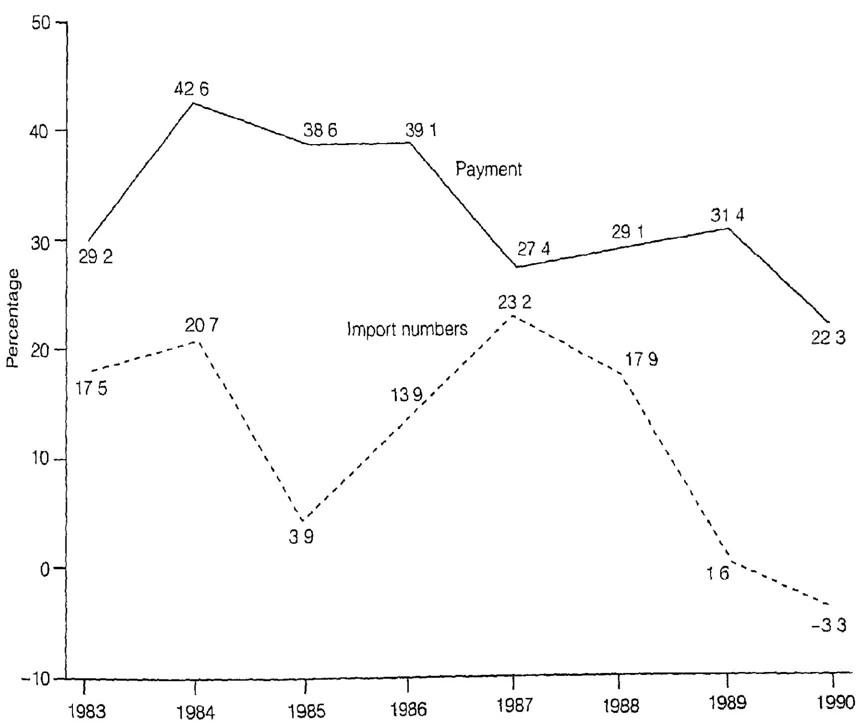


Figure 1. Trend of technology import
Source. KITA. 1991. *Yearly report on industrial technology*

Table 4. Technology import by country, industry (1990, million US $)

Industry	US	Japan	Germany	France	UK	Others	Total
Food and beverage	5.5	1.7	0.3	0.8	—	1.2	9.5
	(9)	(6)	(–)	(1)	(–)	(2)	(18)
Textile	6.0	2.9	0.5	2.7	0.6	2.0	2.0
	(6)	(13)	(1)	(7)	(2)	(15)	(44)
Chemicals	89.1	62.9	24.1	11.4	14.2	15.4	217.1
	(35)	(62)	(13)	(5)	(8)	(15)	(138)
Metal and non-metal	6.7	7.3	3.2	2.6	3.4	1.0	24.2
	(11)	(24)	(3)	(1)	(3)	(5)	(47)
Mechanical	39.4	126.6	17.5	3.1	25.9	20.1	232.6
	(30)	(103)	(21)	(6)	(10)	(18)	(188)
Electric/electronic	284.2	130.4	3.4	2.1	—	47.6	467.7
	(19)	(87)	(13)	(1)	(4)	(13)	(219)
Electricity	64.7	0.6	7.2	6.2	—	1.2	79.9
	(3)	(–)	(–)	(–)	(–)	(–)	(3)
Others	18.5	9.2	3.1	1.0	0.6	9.1	41.5
	(26)	(38)	(4)	(4)	(1)	(12)	(85)
Total	514.1	341.4	59.3	29.9	44.9	97.6	1087.0
	(221)	(333)	(55)	(25)	(28)	(76)	(738)

Note. Figures in parentheses represent the number of concerned industries in the respective countries.
Source. KITA. 1991. *Yearly report on industrial technology.*

technology import from US and Japan, amounting to 75 and 79% of the added import from both countries in terms of number and payment respectively (Table 4).

As private conglomerates internalized technological innovation in the 1980s, technological export began to increase from the areas of old technologies and non-competitive industries. Joint ventures encouraged the migration of factories resulting in the export of labour intensive technologies. Recently, 'Nordpolitik'[2] perpetuated this kind of technology export to socialist countries like China and Russia. However, till 1990, the total number of technology exports and amount of earnings remained 185 cases and 147 million dollars respectively. In the 1990s, the numbers and earning have increased significantly as compared to previous years. As Table 5 shows, the technology export is concentrated in the regions of southern and northern Asia, indicating a concentrated pattern of technology export to underdeveloped countries. In 1990, technology export constituted 36% of direct investments, 30% of industrial property related technology, and 29% of trademarks and patents.

As a conclusion, the imbalance in technology import and export has worsened, particularly in 1990, despite the rapid increase in technology export. Trade deficit in technology transfer exceeded a billion

[2] Since the 24th Olympic Games held in Seoul in 1988, Korea has sought to establish economic and political relations with socialist countries resulting in the normalization of the relations with Hungary in 1989, the Soviet Union in 1990, China and Vietnam in 1992, and the opening of economic relations with other Central and East European countries. This northward politics is called 'Nordpolitik'.

Table 5. Technology export by region ('000 dollars)

Region	1978–1986	1987	1988	1989	1990
North America	330	—	3 128	921	4 260
	(2)		(3)	(4)	(5)
Europe	220	275	35	2 116	6 361
	(6)	(–)	(–)	(3)	(3)
North Asia	311	—	—	490	1 884
	(1)			(4)	(10)
Middle East	88 853	5 172	1 321	618	1 345
	(30)	(4)	(–)	(1)	(1)
West Asia	1 824	737	469	262	722
	(11)	(7)	(2)	(4)	(3)
South Asia	3 725	1 617	1 996	3 682	6 857
	(21)	(2)	(10)	(12)	(25)
Africa	1 642	1 310	1 946	2 344	216
	(6)	(1)	(–)	(–)	(1)
Others	—	—	—	50	150
			(1)	(2)	(3)
Total	96 905	9 111	8 895	10 483	21 795
	(77)	(14)	(16)	(30)	(51)

Note. Figures in parentheses indicate the number of technologies exported.
Source. MOST (1991)

dollars for the first time (Table 6). The need of technology import in high technology, and the weakness of R & D capabilities is expected to continue for a while with the current trends in technology transfer.

2.4 Policy reforms facilitating technology transfer

2.4.1 Introduction

Along with the necessity of abating CO_2 emissions, upgrading of technological levels to regain export competitiveness is urgently required in Korea. Technology transfer and R & D needs became so es-

Table 6. Balance sheet of technology transfer (million dollars, %)

Technology transfer	1983	1984	1985	1986	1987	1988	1989	1990
Export (A)	18.9	16.9	11.3	11.7	9.1	8.9	10.5	21.8
Import (B)	149.5	213.2	295.5	411.0	523.7	676.3	930.0	1087.0
A/B	12.6	7.9	3.8	2.8	1.7	1.3	1.1	2.0

Source. MOST (1991)

sential that Korea identified the factors which would affect the flow of technology, and developed approaches to promote technology transfer.

Technology, particularly commercial technology, is generally held by companies either as proprietary information or as formal IPRs. The efforts of businesses to develop technology, and their willingness to participate in technology transfer, are determined by the institutional environment. Recent efforts of the Korean government to improve legal framework and policy measures for technology transfer are provided in the following section.

2.4.2 Legal and institutional framework

Property rights

The adequate and effective protection of IPR is significant to the expansion of international trade and to the free flow of technology among nations. Patents, trademarks, industrial designs, trade secrets, copyrights, and computer programs are protected by separate laws in Korea.

Patents. The patent system grants the patentee the right to exclude others from making, using, or selling his/her invention for a certain duration under the condition that the rights holder is obligated to open his/her invention to the public. To be patentable, the invention must have novelty and innovative industrial application. The protection for the devices is governed by the Korean Utility Model Law. Under the Korean Patent Law, anyone who desires to protect an invention is required to file a patent application with the Korean Industrial Property Office (KIPO). After the examination of an application and review of public comments, KIPO authorizes and registers the invention as a patent.

The duration of patent protection is 15 years from the date of the patent publication, and shall not exceed 20 years. Use or sale of a patented invention, without the right holder's authorization, is subject to civil or criminal liabilities. A non-voluntary licence may not be granted unless there exist compelling reasons for granting it. An application for a non-voluntary licence can be made on the following grounds: inaction or lack of the patent; insufficient utilization; in case of emergencies like natural disasters; when necessary for national defence and public interest; and in case of a dependent invention. Through a revision of the Patent Law in 1989 and in 1990, Korea has adopted a comprehensive patent system. The duration and the scope of patent protection have been extended to 15 years and includes chemicals, pharmaceuticals, micro-organisms, foods, beverages, and related products.

Trademarks. Trademarks, which too are registered in KIPO, are also protected by the Trademark Law. The duration of the trademark protection is 10 years and can be renewed at the end of this period for 10 years more. In 1990, this law was revised to strengthen the right of the trademark, including extension of the non-use period for cancellation from one to three years, partial nullification (relating to one or some of the goods or services for which the mark is registered), and allowing the trademarks to remain independent of the transfer of a specific business. Another unique feature of this system of trademark is the protection of well-known trademarks even if they are not registered in

Korea. KIPO rejects applications for the registration of a trademark if the mark is the same or similar to that of a foreign trademark. Industrial design is protected for eight years, and particularly well-known international industrial design is protected by the recent law regardless of non-registration.

Trade secrets. The Unfair Competition Prevention Law (UCPL) protects trade secrets and maintains order in commercial trade, preventing competition by means of unfair business methods such as the illegal use of trademarks or tradenames. The major contents of UCPL are provisions for anti-counterfeiting activities and provisions for 'trade secrets' protection. The term 'trade secrets' encompasses technical or business information including manufacturing or management know-how which (i) is not generally known; (ii) has independent economic values; and (iii) has been kept secret by reasonable efforts. Violation of trade secrets protection constitutes unfair competition under the law which may be subject to civil remedies and criminal sanctions.

Copyrights. The copyright governed by the Copyright Law protects the expression itself as embodied in the copyrighted work, for which the work must be an original intellectual creation. There are several other laws protecting copyrights including literary, artistic, musical, photographic, cinematographic works, and computer programs. An author is not required to register his/her work. Works of foreigners who are nationals of the member countries of the Universal Copyright Convention are treated at par with Korean nationals. The Computer Program Protection Act provides comprehensive copyright protection for computer software. A copyright expires 50 years after the author's death. Remedies for the infringement of copyright include payment of damages and restoration of reputation. Infringements are subject to criminal sanctions.

Measures for technology import

Relaxation and simplification of the regulations and procedures for technology import are among the major measures to expedite and liberalize technology transfer. For example, the approval system of reviewing on a case-by-case basis has been replaced by a regularized system. Further, technologies which were earlier subject to report now only require certification by a 'Class A' foreign exchange bank. Under the current system, a contract for technology import is either subject to report or requires only bank certification.

According to the Foreign Capital Inducement Act, technologies subject to report are contracts whose terms either exceed three years, or whose terms of payment exceed US $100 000 for licensing fee or US $50 000 for royalty. The defence related techniques/technologies are also subject to report. The relevant minister shall make decisions on acceptance not later than 20 days from the filing date of the report. Non-acceptance of the report on technology transfer contracts mainly occurs when either the main purpose is primarily to obtain a monopoly sales right or primarily to sell raw materials, parts or accessories, or when the contract violates the Monopoly Regulation and Fair Trade Act.

In order to accelerate technology transfer, the government also provides tax exemption for advanced technology which is essential for the national economy but is too advanced to be developed

domestically. The licensing fee received by the technology licensor shall be exempted (100%) from income and corporation tax for five years.

The technologies which require only 'Class A' foreign exchange bank certification are those not subject to report, and which are under the Foreign Exchange Control Act. In such cases, the bank shall make the decisions on certification within two days and there are no grounds for non-acceptance. However, there is no tax exemption.

Measures for technology export

Technology export has been systematically encouraged under the Technological Development Promotion Law. Under this law, Koreans are permitted to use/enforce industrial rights or any other technology for foreigners. The scope of technology export includes any contract offering technical engineering service and know-how except overseas construction engineering services.

When the total royalty receipt exceeds US $100 000, the technology exporter must submit reports to MOST—their technology export plan (including such items as content and offered methods of technology), cost of export, and receiving methods, etc. In the case of security related technology, the exporter must receive the approval of MOST, regardless of the amount of royalty. MOST, in consultation with the Ministry of Commerce and Industry, then obtains a recommendation from the Ministry of National Defence if the technology is related to defence.

Policy for future technology development

Parallel to the promotion of technology transfer, Korea is strengthening its institutional base making it conducive to increased R & D activities by industry, university, and research institutes. Major contents of the technology development plan are the increase of financial investments, cultivation of high quality personnel, intensive support for critical technology, and promotion of private role and engineering services.

The government has plans of increasing the budget for S & T to finance the development of core technologies, human resources, and S & T infrastructure. A Technology Promotion Fund will be mobilized to support the development of key core technologies, and public enterprises will be required to invest a certain proportion of their sales into technology development.

To encourage R & D investment by the private sector, the government will strengthen the existing assistance such as the financial, tax, and procurement programmes. To provide financial support, KTDC plans to expand to the Korea Technology Financial Corporation, by merging the Korea Development Bank with other financial institutions. Tax deduction for private investment in R & D will be increased and a special depreciation rate will also be applied for R & D equipments and facilities. In addition, an 80% tariff reduction is planned for the import of equipments and materials for R & D. To expand the demand for new products, the present bidding system, which is solely based on price, will be expanded to include quality and technological contexts.

As was the case in the last three decades, expansion in qualified technical manpower is essential for the development of high technology. Korean government assistance for technology manpower is

Table 7. Technology investment plan (billion won)

Investment	1992	1993	1994	1995	1996
S & T	5976.00	7201.00	8734.00	10576.00	12820.00
S & T /GNP(%)	2.63	2.82	3.03	3.25	3.49

Source. Ministry of Trade, Industry, and Energy (MOTIE)

not administered by a comprehensive programme *per se*. It is carried out as a part of general technological innovation assistance programmes, such as tax benefits and special financial incentives. According to future plans, university programmes and education at primary and secondary school levels in S & T will continue to be strengthened. In particular, the enrolment in selected engineering colleges and the KAIST will be increased. A joint appointment system of professors and research scientists and 'post-graduate education' systems will be adopted by the government. Korea's technology investment plan is examined in Table 7.

The industry's internal training programme will also be supported. Particularly, core technologies are being intensively supported. Seven production technologies (in the fields of highly integrated semiconductors, ISDN, high definition televisions, electric vehicles, intelligent computers, medicine) and seven fundamental technologies (in new materials, machinery, biotechnology, environmental technologies, new energy, atomic energy, and human factors) have been selected for intensive support through inter-ministerial collaboration.

Rapid changes have led Korea to develop self-reproducing technological capabilities domestically. During this stage, R & D was increasingly emphasized for the indigenization of highly advanced strategic technologies and promotion of the industry's technological self-development. Private conglomerates called *chaebols*, established and expanded their own research institutes. As shown in Table 8, the dominant role of the government in the development of S & T is being substituted progressively by private industry R & D. Originally relying on government sponsored S & T development, conglomerates in the 1980s sought to develop their own research centres.

As at the end of March 1992, there were 1745 private institutes, including 739 institutes established by small and medium sized companies. In addition, Korea currently has 64 research consortia

Table 8. S & T investment and R & D expenses (billion won)

	1965	1975	1980	1985	1990
S & T Expenses	2.10	62.00	317.00	1286.20	3800.00
Percentage of GNP	0.26	0.61	0.86	1.65	2.28
G/P[a]	90:10	—	68:32	28:72	25:75
Private R & D Institute	—	—	65.00[b]	183.00	966.00

[a] The ratio of government to private sector S & T spending. [b] 1981 data.
Source. KITA. 1991. *Yearly report on industrial technology*; Lee 1988

involving a total of 1415 member companies, of which 41 consortia are formed by 1000 small and medium sized companies. The government supports the extension of private research institutes and research consortia through financial aid and tax privileges on research facilities and equipments.

3 Technology transfer in the power sector

3.1 Introduction

This section investigates patterns and mechanisms for technology transfer in the power sector and their relations to institutional development. The power sector in Korea manifests the general pattern of technology transfer, and of economic development policy as well. After the Korean War (1950–1953), the southern part of the peninsula had very limited infrastructure on which the economy could rely on for development. Transportation had received some attention during colonial occupation. A system of political administration and an education system had also been developed. Only few industrial sites were usable. However, virtually all commercial energy facilities were located in the North. If the South Korean regime was to lead the country to economic recovery, it would have to quickly organize a power complex[3] which could serve the needs of development. The provision of commercial energy became a priority for the first and subsequent development plans.

The state assumed the role of directing national energy development by marshalling the society's resources, designating the corporate participants, and reserving for itself all major decisions on technology and its integration into the economy. At the same time, companies (including those created by the state) responded to the governmental policy by seeking vertical and horizontal integration of technologies and industrial activities necessary to realize the government's commercial energy plans. A partnership model is in evidence from the beginning of these power projects. The state, public utilities, corporates, and large foreign conglomerates have closely combined to create an institutional network of energy and industrial production. Through the combined efforts of these private and public institutions, Korea has achieved the indigenization of technology in the power sector. Initially the country was dependent on foreign capital and technology and pursued a strategy of technology transfer with regard to power plant design, construction, engineering, and management, with the aim to indigenize. Further, these projects served as technology and capital acquisition opportunities which were subsequently leveraged by companies to establish favoured status in domestic and, even more importantly, in export markets.

Technology transfer in the power sector in Korea has evolved over three phases. The first phase, covering the 1950s and the early 1960s, was a formative stage. Foreign technology and capital were used to construct electric plants for the immediate supply of electricity, and contributed to the formation of a corpus of domestic engineers and technicians. The second phase (the 1960s and the early

[3] The generation and distribution of electricity is closely linked to related techniques. The combination of particular energy resource with technique is called power complex (Mumford 1967).

1970s) focused on building an electric network and indigenizing the foreign technology. Engineering and technical experiences, especially in hydro and coal- and oil-fired electric power technology, were incorporated into the state utility, industry, and research centres. Both the first and second stages of development were institutional preparations for the introduction of nuclear power/technology into the Korean energy system.

In the late 1970s and 1980s, the country adopted indigenization and entered the nuclear era. Previously developed institutions were fully integrated to collaborate for the indigenization of power technologies in the construction of nuclear power plants. These three phases of indigenization in the power sector are described below in Table 9. The evolution of power-related institutions built up over three decades prepared Korea for an extensive nuclear programme involving power reactors, research reactors, and nuclear fuel cycle facilities. With its pursuit of nuclear power, Korea took advantage of the centralized energy institution that was already in place.

As a result of ambitious national plans, the electricity system has grown rapidly, including installed generation capacity, the scale of power generation, the unit size of power turbines, the efficiency of power generation and distribution, as well as the expansion of the transmission and distribution network (Table 9). The installed capacity for electricity generation increased from 367 MW in 1961 to 21 110 MW in 1991, a 58-fold increase. The past build-up took place mostly through building thermal steam powered plants and internal combustion plants. Recently, the share of nuclear power has increased sharply. From January to September 1992, nuclear power contributed to 43% of the total electricity generated in the country.

Table 9. Growth of the electric power system

Parameters	1961	1981	1991
Installed generation capacity (MW)	367.0	9835.0	21 110.0
Hydro	143.0	1202.0	2445.0
Thermal/steam	223.0	6812.0	9912.0
Internal combustion	1.0	1234.0	1138.0
Nuclear	—	587.0	7616.0
Transmission lines (total length in km)	18 596.0	48 604.0	103 384.0
Distribution lines (total length in km)	36 968.0	330 811.0	642 472.0
Peak load (MW)	306.0	6114.0	19 123.0
Average load (MW)	202.0	4590.0	13 541.0
Load factor (%)[a]	66.2	74.7	70.8
Average utilization factor (%)[b]	55.1	46.7	63.8
Transmission and distribution loss (%)[c]	29.4	6.7	5.6
Gross power generated (GWh)	1773.0	40 207.0	118 619.0
Power sold (GWh)	1189.0	35 424.0	104 374.0
Power consumption per capita (kWh)	46.0	915.0	2412.0

[a] Average load/peak load. [b] Annual gross generation/(nominal installed rating × 8760 hours/year). This ratio is sometimes referred to as the plant factor. [c] Net generation − power sold/net generation × 100.
Source. KEPCO. 1992. *Financial Statistics*

3.2 Technocracy formation

Electricity was introduced in Korea in the late 19th century and extensively developed by colonial forces at the end of 1920s. Most of the electricity, particularly hydro-electricity, was generated in the North where the electric-chemical heavy industries for military purposes were concentrated. At the time of liberation in 1945, the South depended heavily upon the North's hydro-electric power system to supply power to its industry and urban residential sectors. Disruption of this power source by the North in 1948 exposed the South's vulnerability and led to the rapid construction of hydro-electric power stations and coal-fired plants in the South. Faced with the immediate need to compensate for the loss of electricity from the North, Korea embarked on a plan to construct power plants on a turnkey basis with the aid of foreign finance and engineering companies. Imports from the US, Japan, the Federal Republic of Germany, France, the UK, and Switzerland provided the technology and capital necessary for the creation of an electric power network . There was, therefore, no indigenization of foreign technology during the period, but the number of engineers, scientists, and constructors increased greatly.

3.3 Building of power institutions

As Korea underwent a period of rapid urbanization and industrialization in the 1960s, the country turned its attention towards the establishment of an indigenous power technology base as a part of the country's overall industrial development strategy. A single utility electric system was created by merging the three existing utilities into one public corporation called KEPCO. KEPCO was given the responsibility of establishing and implementing a technology transfer programme in electric power. KEPCO engaged in project management, and developed power plant technology, through the operation of training programmes for its engineers and technicians. Apart from this, its personnel participated in the new power plant projects built by foreign companies. KEPCO promoted the use of composite teams consisting of their own staff and staff from participating corporations. Further, KEPCO staff and engineers were mobilized to inspect power plant equipments for quality assurance and to give advice on technology design and development.

With the aid of the government-sponsored Korean Society for the Advancement of Machinery Industry, KEPCO was able to control the selection of transferable items and eligible domestic firms, and oversee inspection and testing of domestically produced equipment. Domestic firms were selected to produce indigenous goods, which were usually financed by banks controlled by the central government. In this way, the state laid the groundwork for development of an indigenous technical capacity in energy production. To accomplish indigenization, the government intentionally relied upon large domestic conglomerates such as Hyundai and Daewoo to replace foreign sources in plant construction and equipment supply, and to concentrate on technology transfer (Jong-dall 1991).

The partnership model was used systematically to foster indigenization, calling upon Hyundai and Daewoo to organize engineering companies in 1976. They played a major role in the state's efforts to create domestic manufacturers of power plant technology and acquired knowledge about new

power plant techniques through technical collaboration with foreign companies. These agreements facilitated the supply of basic design documentation, technical information, the deployment of foreign engineers in their companies, and the training of their personnel. With the government policy in 1976 outlawing turnkey power plant projects from foreign companies, domestic corporations were handed a protected technology market. 'Local content ratios'[4] for various types of power plants were used to force the employment of domestic equipment and engineering.

The supply of auxiliary equipment for power plants, such as wire and transmitters, was also assigned to other large scale domestic firms such as Hyosung Heavy Industries, Gold Star Instrument and Electric Company, Hyundai Electrical Engineering Company, and others. Government and foreign collaboration agreements were used again as an important means of technology transfer. The national government played a key organizing role by selecting and partially financing certain corporations for this work. The corporations involved were able to use this production work as a technological learning opportunity. According to one study (Lee, Sharan 1985), auxiliary equipment requirements of power plants served as important inducements for the technological build-up efforts of Korean companies. The engineering and production complexity associated with this equipment demanded relatively high performance and accuracy standards.

3.4 Indigenization of power technology

Once the power technocracy and institutional network had been framed, domestic corporations gradually became independent of power plant engineering and equipment companies. By 1976, Korea had achieved an electricity regime in which the close collaboration of the state, private conglomerates, and science created a sophisticated technical capacity for the designing and production of electrical technology. Through collaborative production settings, the state and domestic conglomerates were able to acquire the necessary expertise and knowledge to become independent producers. In this process, public and private organizations such as KEPCO, Hyundai, and Daewoo began to indigenize power technologies.

In the case of nuclear power technologies, domestic nuclear technocracy had taken shape through the 1960s and 1970s, involving a process of assessment of foreign factors and power plants, and participation in conferences and consultations with the International Atomic Energy Agency and the US. These nuclear technocracies played essential roles in the development of nuclear related institution networks, including the establishment of university departments, engineering and heavy industries, and research centres. On the other hand, engineering and equipment manufacturing technologies were accumulated by domestic power plant companies.

The Korean Atomic Energy Research Institute (KAERI) was established in 1959 for the construction and operation of the purchased research reactors which began operation in 1962. KAERI

[4] The government annually assigns a ratio of local participation in each type of power plant project.

mobilized the country's pool of scientists in the development of the Korean nuclear programme and in the formation of a nuclear technocracy. In 1968, Korea went ahead with the construction of two 500 MW units, each to be completed in the mid-1970s. Responsibilities for the construction and operation of the plants were assigned to three governmental agencies: (i) KEPCO—for the engineering, construction, and operation of the plants, (ii) KAERI—for the R & D of nuclear power technology, fuel, and safety controls, and the training of nuclear engineers and technicians; and (iii) the EPB—for the co-ordination of the Korean nuclear power programme, negotiation for foreign loans and the preparation of feasibility studies (Ha 1982).

In order to indigenize nuclear fuel cycle technology, the Korea Nuclear Fuel Development Institute was established in 1976. The establishment of Korea Power Engineering Corporation (KOPEC), a KEPCO subsidiary, in 1976, completed the institutional framework with a public utility (KEPCO), the state (MOER, MOST), science centres (KAERI), and already developed corporate institutions. KEPCO was given the sole responsibility for construction and operation of all nuclear power plants and, using its monopoly status, to force inclusion in collaboration agreements with foreign vendors of the sale of design documents, the participation of domestic firms in the production of specific equipment, and foreign technical assistance or training of Korean engineers and workers. Central services such as project management and design and construction engineering were identified with specific foreign companies by KEPCO, and then overseas on-the-job training was arranged.

In order to systematically indigenize nuclear technology, the national government decided in 1978 that the Korea Heavy Industry Company monopolize all nuclear engineering and major equipment production. This forced conglomerates to move into the international nuclear market. Recently, though, the *chaebol* sector has been pressuring the government to reopen the domestic power market as well.

Figure 2 shows the progress of indigenization for the hydro, thermal, and nuclear power plants respectively. For all the power plants, the local content ratio in the total power plant equipment demonstrates an increasing trend over time. This progress is more apparent in the hydro and small thermal power plants.

Due to the less technological complexity involved, the indigenization progressed faster in auxiliary equipment and boilers, while it hardly progressed in turbines and generators because of their advanced technology. The indigenization of engineering components appears to have proceeded in a very uneven manner, reflecting on the performance of different engineering companies involved. In nuclear power plants, the record of indigenization has been much more modest. The slower progress may be attributed to higher technological complexities in nuclear power technology and limited experience in this field. The technological capacity built up in indigenizing thermal power equipment is used for export purposes and acceleration of indigenization of nuclear power plant equipment. Corporate engineering, construction, and manufacturing companies and their subsidiaries expanded into the international markets, filling export orders for turnkey power stations and other industrial plants in countries such as Saudi Arabia, Libya, United Arab Emirates, and Malaysia.

While the level of indigenization increased quite significantly, the domestic firms still face numerous technological problems. They still have to resort to the import of critical intermediate inputs

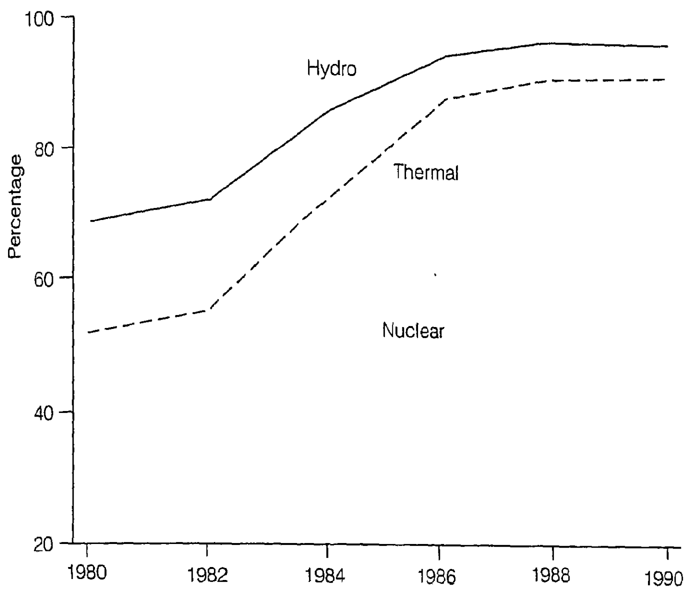


Figure 2. Trend of local content ratio for power plants
Source. KEPCO

to a significant degree. The government has worked out targets for local content ratio for different types of power plants and equipment. According to the plan, the thermal power plants scheduled to be constructed after 1996 will be indigenous. Even for nuclear power plants, the targeted local content ratio is quite high (Table 10).

In case of nuclear power technology, each local content ratio is counted on the basis of manufacturing techniques. Design techniques are not included. If both techniques are counted, the local content ratio will be lower than current ones. For example, the target local content ratio of Youngkwang plants which are scheduled to operate in 1996 is 74.5%.

Table 10. Target local content ratio

Plant type	Equipment	1992	1993	1994	1995	1996
Thermal	Boiler	89.9	91.1	92.7	92.9	92.9
	T/G[a]	85.6	88.1	88.7	89.2	90.9
	Total	88.4	90.1	91.2	91.6	91.9
Nuclear	NSSS[b]	81.5	84.4	86.6	87.0	87.0
	T/G	97.0	98.0	98.0	98.0	98.0
Total		90.9	92.7	94.3	95.0	95.0

[a] Denotes turbine and generator. [b] Denotes nuclear steam supply system.
Source. KEPCO

3.5 Conclusion

The transfer stages of the power sector in Korea, including nuclear power, reflect the pattern of technology transfer in general and national industrial development. Relying initially on foreign capital and knowledge, the state, public, and private corporations organized a highly systematic partnership order. Adopting a planning structure, these same institutions were then able to indigenize technological development and direct the economy along a corporate path. In the Korean experience, public and private conglomerates provided the capital, as well as engineers and technicians, to secure an oligarchic position in industrial production—particularly, in power production. Essential to the technology transfer process has been the establishment of political control over the power sector.

In general, the Korean experience of technology transfer in the power sector has been successful so far, though they still lack basic engineering capacity and the know-how to design some of the major equipment. This however can be achieved by a systematic indigenization policy and development of related institutions. The indigenization policy was devised as part of a much broader capital goods sector development programme—in other words, as a part of the country's industrial development strategy. Corresponding institutional arrangements were also critical in the formulation and implementation of the indigenization policy in the power sector.

According to one study, (Lee, Sharan 1985) however, the cost of technology transfer in Korea has been high because of the extensive reliance of the local firms on transfer agreements based on very considerable import contents, and partly because of non-standardization. Contrary to the Indian approach, which was to use technical licensing agreements in a more limited way, Korea's approach laid emphasis on achieving higher quantitative targets of production in a short time by its own enterprises, but with less attention to the technological contents.

Another lesson from the Korean power sector is in the fact that there have been no attempts to prescribe standardized specifications for choosing the main equipment in various power stations. Had there been a systematic policy for standardization, the time and finances required for transferring power technology would have been greatly reduced.

In conclusion, the successful indigenization of the power technology in Korea was preceded by a long period of learning symbolized by institutions such as public utilities and private large corporations. The unique institutional arrangement which brought about the success will also continue to function in the foreseeable future.

4 INDIGENIZATION OF COGENERATION TECHNOLOGY

4.1 Introduction

Cogeneration—the sequential production of electrical energy and thermal energy, from a single process—has the potential to produce this combined energy with 20 to 30% less fuel than would be required by separate electric power and thermal processes. Thus, the importance of cogeneration in

Korea, has been emphasized as an energy conservation measure as well as an environmental strategy. It has recently been highlighted as an efficient way to cope with global warming, because of its expected contribution to limiting CO_2 emissions. Moreover, it can mitigate many difficulties recently faced by KEPCO and the government, such as spatial constraint and financial shortage to develop such large nuclear power plants.

Cogeneration power is a recent phenomenon in Korea. Thus, transfer and development of cogeneration technology is at a nascent stage. However, many of its technologies, excluding core techniques such as those of the turbines, have been transferred through the involvement of domestic corporations in power plant projects. Conglomerates like the Hyundai Heavy Industry have expanded their cogeneration business to foreign markets. A small packaged cogeneration system has been recently developed by a corporation and a R & D institute.

Energy related engineers and institutions, formed during the 1970s and 1980s, are involved in the indigenization of cogeneration technology. Public institutes, such as KOPEC, KIST, and Korea Energy Research Institute (KERI), and private corporations, such as Samsung, Hyundai, Hanla, and Baugsan, are the representatives. While some corporations are concentrating on the transfer of gas turbine cogeneration technology, others are focusing on the development of gas engine-driven small cogeneration systems. Cogeneration, combined with the incinerator, is also a new target area for technology development as urban residential/commercial waste is increasing and disposal sites are decreasing. The Korea District Heating Corporation and its subsidiary, the Korea District Heating Engineering Company, were recently organized by the government to manage and transfer cogeneration technology, specifically for district heating.

Technology transfer during the last three decades was initiated and systematically managed by the state and public corporations, but the situation has changed in the recent case of cogeneration technology. The dominant role of the government is being assumed by private companies. Thus, the indigenization of the engineering component in cogeneration power plants appears to proceed in an uneven manner, forecasting the difficulty of standardization and the high cost of technology transfer.

4.2 Current status of cogeneration

Since the 4000 kW cogeneration system in the industrial sector was introduced in Korea in 1960, it has been extensively used in industrial complexes, new townships, and commercial buildings. While total electricity generation in Korea in 1990 increased to 2.2 times that of 1980, the cogeneration capacity increased by five times during the same period, reaching 1584 MW (Table 11).

The cogeneration system covered 7.5% of the national electricity generation capacity (KEPCO) in 1990. It is expected to cover over 10% of the total capacity by AD 2000, according to the government plan. Table 12 shows the current employment and plan of cogeneration by different sectors. Until 1990, cogeneration was mainly introduced in the industrial complex. However, a large number of cogeneration systems for district heating in new towns have since been established. Further construction is also planned.

Table 11. Growth of cogeneration and total electricity generation

		1980	1982	1984	1986	1988	1990
Cogeneration	Plant (number)	20	24	29	36	61	90
	Capacity (MW)	314	337	336	410	1354	1584
	Growth rate (%)	100	107	117	131	431	504
Total generation	Capacity (MW)	9391	10 304	14 190	18 060	19 944	21 021
	Growth rate (%)	100	110	151	192	212	223

Source. Shon (1991), KEPCO (1992)

Petrochemical, paper, and pulp industry were major sectors which employed cogeneration systems because of their high requirements of steam. But these systems were relatively small, compared to those serving the mechanical and steel industry (Table 13). While the number of units was only 15, in the latter sector, the total capacity was 855 MW, indicating the large size of each cogeneration system in the mechanical and steel sector. Again, compared with industrial cogeneration, the size of cogeneration systems employed in commercial buildings is relatively small. Yet, 8.2 MW for one building is not a very small unit.

4.3 Technology transfer in cogeneration

Important technologies in the cogeneration system can be divided into design techniques for each component, engineering techniques for systems composition, and operating techniques for establishment, maintenance, and repair. Considering all these techniques, Korea can be categorized as being at the adaptation stage, while the US and Europe are at the maturing stage, and Japan at the commercialization stage (Table 14).

Table 12. Cogeneration by sector in 1990 and 2000

Sector	Operating (1990)	Planned (2000)	Total
Industry	78	11	89
	(1326)	(487)	(1813)
Industrial complex	4	8	12
	(189)	(572)	(761)
Commercial building	6	—	6
	(49)	—	(49)
District heating and cooling	2	6	8
	(20)	(2100)	(2120)
	90	25	115
Total	1584	3159	4743

Note. Figures in parentheses denote the capacity (MW)
Source. MOTIE

Table 13. Cogeneration size by sector

Cogeneration size	Mechanical and steel	Petrochemical and chemical	Paper and pulp	Commercial building	District heating	Others	Total
Plant (A)	15.0	28.0	19.0	6.0	2.0	20.0	90.0
Capacity (MW) (B)	855.0	368.0	198.0	49.0	20.0	94.0	1584.0
Average size (B/A)	57.0	13.1	10.4	8.2	10.0	4.7	17.6

As discussed earlier, though Korea has been successful in indigenized power technology as well as other technologies through technology transfer, indigenization of cogeneration technology is relatively slow. Major components of cogeneration plants are being built by foreign companies as in the case of a recently completed Bundang plant and other plants (Table 15). In the case of Bundang, single flow and open cycle gas turbines, reaction steam turbines, and generators were provided by the Swiss company, Asea Brown Boveri (ABB). Domestic companies of KOPEC and Hyundai took charge of the basic design and construction respectively. As major components of the turbine and the generator were provided on a turnkey basis, these technologies could not be transferred and indigenization level remained at 7.5%.

The most recent and best case of technology transfer in cogeneration is that of Ildo combined cycle, built in November 1992, in which a domestic company, Korea Heavy Industry Corporation was involved as a major contractor with General Electric (Table 16). The total cost for two units of 940 MW cogeneration was 1.1 billion dollars of which about 38% was paid for foreign technology and royalty. KEPCO tried to indigenize the cogeneration technology by separating the effort into three different areas—management techniques, technician training, and design techniques for boilers. The composition of technology transfer is provided in the following table. As a result of the effort,

Table 14. Level of cogeneration technology

Technique	Korea	Japan	Europe and the US
Prime mover			
Gas engine	AS	AS	MS
Diesel engine	AS	MS	MS
Gas turbine	IS	AS	MS
Generator	AS	MS	MS
Control system	MS	MS	MS
Heat recovery			
Heat exchanger	MS	MS	MS
Absorption chiller	AS	MS	MS
Engineering technique	AS	AS	MS
Operation technique	AS	AS	MS

Note. AS—advanced stage; IS—introduction stage; MS—mature stage

Table 15. Foreign technology in cogeneration plant

Technology	Bundang	Anyang	Ilsan	Buchecn
Capacity (MW)	600	450	600	450
Fuel	LNG/DO	LNG/DO	LNG/DO	LNG/DO
Cost (million won)	308 496	235 152	305 920	242 291
Supplier of major components	ABB	ABB	WH	WH
Constructor	Daelim	Hyundai	Dong-A	Daewoo, Samboo

Note. All constructors are domestic companies
Source. KEPCO

indigenization level reached 60%, but core techniques like that of the turbine were still completely dependent on foreign technology.

In the case of small scale gas engine cogeneration, Korea began to indigenize its core technologies like the engine and the generator. As the government restricts the use of coal or oil in large cities, many commercial buildings are being forced to change their heating systems to gas cogeneration systems. A small-scale gas cogeneration system supplies electric power and heat for hotels, hospitals, and office buildings. In the US, Japan, and Europe, the use of small cogeneration systems has greatly expanded in the commercial sector as well as in the industrial sector, because of their high efficiency and energy saving capability.

Recently, R & D in this area was completed and now commercialization is being pursued in Korea. Korea Energy Technology Institute recomposed a compact gas engine cogeneration system module and performed a test for its stability under variable electric and heat loads. All parts of the system including the engine were domestically developed, and the system now offers 20 kW, 30 000 kcal/h and 70% energy efficiency. For demonstration of the cogeneration system, it has been installed at Back Won Jang Hotel in the city of Dae Jeon. Samsung Heavy Industry developed a gas engine-driven 30 kW cogeneration system in 1991, and a 300 kW cogeneration system in 1992. They are at the stage of commercialization. Each system is composed of a package (engine + generator +

Table 16. Contents of technology import for the Ildo combined cycle (US $1000, %)

Contents	First stage	Second stage	Total
Management for engineering	10 617	9260	19 877
(installation and pilot test)	(59.6)	(63.6)	(61.4)
Domestic technician training	1324	423	1747
(design, maintenance/repair)	(7.4)	(2.9)	(5.4)
Design of waste heat recovery boiler	5876	4896	10 772
	(33.0)	(33.5)	(33.3)

Source. KEPCO

waste heat exchanger) and acts as a heating equipment in winter and an absorption chiller in summer. However, the important parts of the engine and the generator are imported from the US company, Caterpilar.

4.4 Conclusion

The indigenization of cogeneration technology, excluding techniques related to the turbine, is in sight in Korea. Due to its high energy efficiency, cogeneration has received attention from industrial companies and the national government. Since the 1980s, the government has provided financial support as well as legal reforms to facilitate the employment of cogeneration power plants in the industrial sector. As construction of large power plants in Korea faces financial shortage, environmental and spatial constraints, cogeneration has been emphasized as an effective way to cope with these problems.

However, cogeneration does not always save energy despite the high potential for such benefits. Many cogeneration power plants in Korea have begun to reveal the inefficiency of the system because of low operations as well as technical problems. Moreover, government support for cogeneration is not directed chiefly at the indigenization of the technology but also includes construction of power plants, in view of the requirement of electricity supply. Under these conditions, the rapid employment of cogeneration based on a turnkey basis may lead to the domestic industry losing the opportunity to indigenize cogeneration technology, especially in the light of the low energy price.

In the smaller cogeneration sector, the present regulatory system prevents, rather than promotes, the commercialization of gas engine cogeneration technology that has already been developed. As KEPCO is responsible for the supply of electricity throughout the country, privatization of power, including cogeneration, has the potential to disturb a coherent electricity order. Thus, the government is currently evaluating the means and levels of privatization in power production. Technology transfer of cogeneration in Korea depends upon the potential for commercialization. This is, in turn, heavily influenced by the national governmental policy on electricity.

5 Conclusion: transfer mechanism and capacity building

5.1 Slogan *versus* reality

Technology transfer, from industrialized countries to developing countries, is the most vexing and dominant issue in international relations debate. It is seen as a means to promote harmony on a global scale, and thereby achieve equalized development and the prevention of global warming, as envisioned in Agenda 21 (UNCED 1992).[5]

[5] New and efficient technologies will be essential to increase the capabilities of developing countries in particular to achieve sustainable development, sustain the world's economy, protect the environment, and alleviate poverty and human suffering (UNCED 1992)

Within the United Nations' multilateral framework, however, the debate on technology transfer is highly contentious. This is evident from the Rio Convention in which the debate has heightened the conflicts of interests between the industrialized and the developing countries. The conflicts are inextricably linked to ownership and control of technology. Currently, mastery over technology helps define the parameters of economic relations between industrialized and developing countries. The latter lack access to technology—controlled largely by the former. Indeed, access to technology is central to the North–South dialogue. Technology is a key to national power, and its control is central to international power politics. In the restructuring of global economy, technology determines the competitive strength of the nation-states and their extractive capacity with regard to the appropriation of the world's resources.

In Agenda 21, only such ESTs that are not covered by patents or lie in 'the public domain' are accessible to developing countries. As there is still more valuable know-how and expertise in this domain, Chapter 34.9 can also be helpful for developing countries in the transfer of energy efficient and environmentally sound techniques. These techniques need to be listed and selectively transferred for each country's need. 'International information networks' and 'clearing houses', managed by UN bodies, will promote technological partnerships between holders of ESTs and users.

However, in the market, most of the advanced ESTs are protected in the guise of patents or business secrets. For example, while the development of substitutes for chlorofluorocarbons have been emphasized, the developed countries hold the monopoly position in the market and charge over 12% royalty for the transfer of these technologies. In the statement of Agenda 21, Chapters 34.10 and 34.11, 'proprietary technologies' under patent protection and IPRs are available only through commercial and international channels. Considering the need for protecting IPRs as well as the special need of developing countries for the implementation of sustainable development, patents and licences are supposed to be purchased on commercial terms and transferred to developing countries on non-commercial terms, as part of development co-operation for sustainable development (UNCED 1992).

Therefore, without the development of appropriate and practical mechanisms for technology transfer, the transfer of ESTs suggested by the Rio Convention will remain a slogan and maximization of profit by technology holders will result. In addition to the development of mechanisms, the number of recipient countries should be increased to facilitate the expansion of ESTs across the world. Due to the recent trend of technological protectionism, particular groups of countries do not have access to ESTs. This, in turn, works against deters the prevention of global warming. According to the UN document TD/B/C.6/151 1989, in the 1980s, the developed countries already showed insufficient political will in respect of restoration and increase of commercial technology flows to developing countries. They were also implementing protectionist policies in the field of intellectual property in order to safeguard and increase their dominant position in the world market at the bilateral and multilateral levels (UNCED 1992)

5.2 Relocation *versus* transfer

As also envisioned in Agenda 21 (UNCED 1992), technology transfer is usually regarded as the panacea to underdevelopment and environmental problems. Emphasizing the developmental utility of technology, this view foresees increased productivity, protection of the environment, alleviation of poverty and finally, modernization. Although international technology transfer has the potential to facilitate industrial development in developing countries, it has not taken place in many southern countries (Edoho 1991; Galtung 1980). These countries have experienced 'technology relocation' that has reinforced technological dependency. A transfer of technology encompasses any activity wherein a holder makes technologies available and a recipient adopts them. Technology embodied in capital goods stands for industrial plants, production facilities, sophisticated machinery, complex tools, equipment, and so on. Generally termed the 'hardware', these are the physical manifestation of technology. Technology also includes, under the common term 'software', industrial property rights, patents, unpatented know-how, management, organizations, as well as technical information and designs. In addition to hardware and software, it includes the socio-political systems and institutional structures. Thus, the development and use of hardware and software are influenced by the socio-cultural milieu and cannot be divorced from politico-economic contexts and production relations. As Galtung (1980) argues, every technology is associated with a structure that 'produces, filters out, and accepts only the techniques that will be accompanied by such structure themselves'.

Therefore, for the technologies to be appropriated successfully, hard technologies should be accompanied by complementary soft technologies and social institutions, including adequate market and profitability perspectives. Excessive relocation of ESTs, without capacity building, can accelerate the condition of technological and economic dependence for developing countries and an extension of Euro-American global domination, under the name of global environmental protection. Thus, developing countries should build their capacities and skills, and thereby prepare the path for transfer of technology.

5.3 Requirement of a new paradigm for ESTs

Agenda 21 (UNCED 1992) also states the importance of capacity building and proposes to strengthen existing institutions, to train personnel at all levels, and to educate the end-user of the technology. However, capacity building requires a coherent and systemic approach over the long term, especially in the case of new technology which requires new social and economic institutions. Previous technologies—in the main, mostly large scale technical systems—focused on wealth-creating material development, and required the intensive use of energy and environmental resources. The achievement of energy efficient techniques and ESTs depends upon the adoption of effective institutional systems to direct capital and research towards the development or transfer of ESTs. Exploiting the benefits of energy efficiency and environmental protection requires an institutional approach to development that focuses upon sustainability. The following sections explain institutional differences of ESTs from the

previous growth oriented technologies, analyse some barriers in the transition of technology (particularly in the case of energy technology) and finally identify strategic stages for the institutionalization of technology transfer.

5.3.1 New paradigm and institutional barriers

Conventional technological development has focused upon wealth-creation as its primary objective. Driven by economic concerns, the prevailing objectives regarding energy production and use have been couched in terms of supply, not only to secure abundant, low cost energy resources, but also to ensure continuing energy supplies by diversifying the sources utilized. In the conventional growth-oriented energy system, energy decision makers act on the premise that increased energy consumption equals economic growth. Decision makers tend to emphasize the values of stability, reliability, and economic optimization. Social and environmental impacts are treated as external to energy decisions. Energy choices are profit oriented and technology reliant, and focus on centralized, capital intensive systems of production and delivery, capable of providing abundant fuel supplies to meet the requirements of industrial wealth-creation. These principles governs the characteristics of conventional growth oriented energy institutions. National energy policy institutions tend to focus on production incentives, reliability-focused regulations, removal of market imperfections, and standardization of technologies and delivery systems. Market institutions are characteristically supply oriented, capital intensive, and focus on technology. Prices reflect fuel competition among systems of production that tend toward monopoly. Technology institutions focus on the development of large scale, centralized, and interconnected supply systems that can meet the demands of the prevailing system of energy production and delivery. Energy related aid institutions tend to concentrate on supply oriented programmes centred around proven technologies of industrial nations. Financial institutions tend to give priority to the capital needs of large investors (producers), supporting large scale projects to maintain technology expansion.

By contrast, in a sustainable growth orientation, the energy technology goals concentrate on achieving end-use efficiency in the delivery of energy services. The goal of energy efficiency tends to incorporate a concern for integrated resource planning that evaluates a wide array of supply and demand options for addressing energy needs. The energy system seeks to create conditions that support long term sustainable development, responsive to anticipated future energy needs as well as current energy demand. These system-goals guide and structure the characteristics of sustainable growth oriented energy institutions. National energy policy institutions concentrate on efficiency (rather than production) incentives, service-focused regulations, and the creation of new, diversified institutions, technologies, and delivery systems to promote a wide array of least cost energy services. Technology choice is guided by the criteria of long term efficiency improvement and resource conservation. Energy markets are innovation-oriented and responsive to competition among a diversity of low capital projects for delivering least-cost energy services. Prices reflect the social/environmental costs of

service options and the competition among diverse service providers. Technology institutions focus on the development of numerous small-to-moderate scale decentralized systems, responsive to user needs, rather than prevailing systems of production and delivery.

The transfer of ESTs for sustainable development requires a number of distinctive institutions that are different from those of the conventional growth oriented system. Since a sustainable growth system focuses on decentralized delivery of efficient energy services to diverse users, there is an important institutional demand to disseminate public information on energy options and their end-use efficiencies. In addition, the internalization of social/environmental impacts, in the choice among energy options, creates an additional institutional requirement for wider community participation in energy choice than is the case under the conventional growth oriented system. Moreover, interdependency of energy choice with environmental protection requires new environmental institutions aligned with energy institutions.

Reversing or halting the inertia of conventional energy intensive technologies faces major barriers. On the one hand, there are the barriers within the existing institutional arrangement. In our study on four Asian countries including Korea (Byrne *et al* 1990), the following are the most crucial barriers within the existing institutional arrangements.

(i) Lack of institutional capacity for enforcement of current policies—the lack of stable and continuous financing for energy efficiency and of qualified personnel.
(ii) Lack of incentives for energy conservation which are mainly due to distortions in fuel prices and misplaced incentives.
(iii) Lack of systematic feedback and evaluation of existing efficiency efforts which encourage positive activities towards energy efficiency programmes.
(iv) Uncertainty of energy consumers' behaviour. Experience shows that promotional activities and demonstration programmes are necessary to promote energy efficiency programmes, which are often hindered due to consumer misconceptions.

To overcome these barriers, changes, which involve a strengthening of the capacities of existing institutions to meet new responsibilities, is necessary at the policy level. At another level, existing institutional arrangements may themselves pose barriers. To overcome a problem of this type, it may be necessary to focus on needs for new institutions and policies that will encourage systematic development of energy efficient and environmentally sensitive technologies and approaches.

5.3.2 Strategic stages for capacity building

Korea's success, and Nigeria's failure, both illustrate the same point—that successful technology transfer occurs when the recipient country has evolved the indigenous capability to acquire, assimilate, utilize, diffuse, and institutionalize imported technology into the development process (Edoho 1991).

Acquisition capability
Acquisition capabilities include the skills and ability to screen, select, and acquire technology. They also include the knowledge to assess the value and cost of technology, skills to bargain and obtain favourable conditions upon transfer, knowledge to evaluate the utility of technology to the economy, and knowledge about 'know-how'.

Assimilation capability
The assimilation capacity includes ability to absorb complex technical information. The real trouble in technology transfer is not merely a shortage of specific skills, but a more general and pervasive lack of skills and abilities to absorb and diffuse.

Utilization capability
Technology transfer occurs when techniques are thoroughly digested and internalized through use. This means the inculcation of skills, corresponding to the complexity of the technology, enabling the recipient country to utilize it on its own. The utilization capacity explains the extent to which imported technology is localized and anchored in the national economy and the extent to which a country progresses from technological dependence to self-reliance.

Diffusional capability
Diffusional capability occurs when there is a turnover of trained and skilled personnel, who use the acquired skills for establishing new indigenous firms. The recipient country can augment its man-power through training acquired by its personnel, only if there is a high rate of staff rotation in the subsidiaries.

Institutional capability
Technology transfer must be in a form that allows the recipient country to integrate the technology into the society. This implies the need to institutionalize technology, in order to enable the recipient to exercise control over it. Technology can then be compatible or convivial with the society.

These five functional capabilities cannot be realized by merely relocating production plants and industrial facilities. Although import of capital goods can be a useful way of acquiring technical skills, it does not represent technology transfer. The extent to which capital goods can foster technology transfer depends on the level of indigenous capabilities existing in the recipient country. These capabilities do not automatically accrue to passive technology recipients. They can be obtained only if recipients participate in all phases of industrial projects, from pre-investment to production.

5.4 Conclusion

Through the Rio convention, the world realized the need for protection against global warming, and of technology transfer in ESTs. Simultaneous development of transfer mechanisms and of capacity building are necessary for the realization of technology transfer. However, it will take a considerable

time for organization and implementation of transfer mechanisms in the world community because of the inextricable linkage of technology ownership to international power politics. Parallel to their participation in the development of transfer mechanism, recipients countries need to prepare their societies for adoption of ESTs by building capacities.

Korean experience of capacity building in technology in general, and power technology in particular, has been the major content of this paper. The partnership of the state, private and public corporations, and R & D institutions is essential for the indigenization of industrial technology and power technology in Korea. According to this experience, optimal use of co-operative work between the state and market can make technology transfer benefit society. Private enterprise, as the principal holder of patents and the repository of technological expertise, should be involved in mechanisms conducive to the transfer of ESTs.

In the case of ESTs, regulations and economic situations may be such that they may not be the most profitable for the one chooser. Moreover, the diffusion of these technologies within the industry is a slow process requiring a great initial investment of human and financial sources, which might not be available. When this diffusion becomes a priority, financial as well as tax incentives need to be created. The most environmentally appropriate technology does imply higher costs for the user, which, in the absence of external funding, will usually lead to its being rejected. To stimulate the fine tuning and diffusion of ESTs, the government needs to create a support programme. It is advantageous—even necessary—to decentralize and localize these activities, which would otherwise be extremely expensive for a central organization to direct. Decentralization has also the added virtue of stimulating local expertise.

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References

1 Byrne J, *et al.* 1990. Institutional strategies for energy efficient and environmentally sensitive development. Report prepared for ESMAP/World Bank.

2 Edoho F M. 1991. Technology relocation and structural dependency: the Nigerian experience with the petroleum Industry. Ph.D dissertation. Delaware: University of Delaware.

3 Galtung J. 1980. The North/South debate: technology, basic human needs and the new international economic order. World Order Models Project: Working Paper **12**.
4 Ha Y. 1982. Republic of (South) Korea. *In* James E K, Onkar S M (eds) *Nuclear Power in Developing Countries*. Lexington, MA: Lexington Books.
5 Kim J. 1991. The political economy of energy-corporate-urban integration in South Korea. PhD dissertation. Delaware: University of Delaware.
6 KITA. 1991. *Yearly Report on Industrial Technology*. Seoul: Korea Industry Technology Association
7 Lee J, Sharan H N. 1985. Technology issues in the energy sector of developing countries: technological impact of the public procurement policy: the experience of the power plant sector in the republic of Korea. New York: United Nations Conference on Trade and Development (**UNCTAD/TT/60**).
8 Ministry of Trade and Industry. 1992. Technology working group report on Korean and US system (**10**). Seoul: Government of South Korea.
9 Ministry of Trade and Industry. 1992. Recent developments in intellectual property laws of Korea (**10**). Seoul: Government of South Korea.
10 MOST. 1991. A study on the development of gas engine cogeneration system for building. Seoul: Ministry of Science and Technology, Government of South Korea.
11 Mumford L. 1967. Technics and human development: the myth of the machine (**1**). New York: Harcourt Brace Jovanovich
12 Seidel R W. 1986. A home for big science: the Atomic Energy Commission's laboratory system. *Historical Studies in the Physical Sciences* 13(2): 375–400.
13 UNTDB. 1989. Report of the Committee on transfer of technology (**TD/B/1203, TD/B/C.6/151**). New York: United Nations Trade and Development Board
14 UNCED. 1992. Transfer of environmentally sound technology, cooperation and capacity building (Agenda **21**, Chapter **34**). New York: United Nations Conference on Environment and Development.

BIBLIOGRAPHY

1 Agence de cooperation culturelle et technique. 1991. *Strategies and mechanisms which favour technology transfers for sustainable development*. Korea: Agence de cooperation culturelle et technique.
2 Agence de cooperation culturelle et technique. 1991. *Financial mechanisms for development and the environment*. Korea: Agence de cooperation culturelle et technique
3 Choi H. 1987. Direction for technological self-reliance: Korean approaches. In HAD policy and planning for technology and development. Prepared by KAIST, UNESCAP.
4 EPB. 1990. Types of unfair competition and regulation guideline on unfair competition in international contract. Seoul: Economic Planning Board
6 Kim J. 1992. Trend of cogeneration technology in commercial sector. *In* Korea Techno Center (ed.) Special seminar on cogeneration technology. 21–39.
7 Kim J, Byrne J. 1990. Centralization, techniquization and development on the semi-periphery: a study of South Korea's commitment to nuclear power. *Bulletin of Science, Technology and Society* **10**: 212–222.
8 KEPCO. 1991. *Financial Statistics*. Seoul: Korea Electric Power Corporation
9 KEPCO 1992. Survey on the self-generation power plants in 1991 (**11**). Seoul: Korea Electric Power Corporation
10 KEEI. 1992. Protection for global environment and direction for energy policies. Seoul: Korea Energy Economics Institute.
11 Lee C. 1988 The role of the government and R & D infrastructure for technology development. *Technological Forecasting and Social Change* **33**: 33–54.
12 Ministry of Energy and Resources. 1991. Yearly report on energy and resources. Seoul: Government of South Korea.
13 Ministry of Finance. 1992. Regulations on foreign investment (**11**). Seoul: Government of South Korea.

14 Park S. 1991. The strategy of technology transfer in terms of political, economical and social aspects. *In* Taiwan Economic Research Institute. (ed.) Symposium on international technology transfer. Seoul: Taiwan Economic Research Institute

15 STPI. 1992. Proposal for policy and institutional reforms to overcome fundamental barriers in technological development. Seoul: Science and Technology Policy Institute

16 Seol Bi Ki Suk. 1991. Special edition for cogeneration technology. *Monthly Journal of Equipment Technology.*

17 Shon H S. 1991. Trend and prospect for cogeneration in Korea. *Boiler*: 38–48.

Role of technology transfer in limiting CO_2 emissions: Thailand's case for cogeneration and energy efficient lighting

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1 Introduction

Previous studies have recommended that the rate of greenhouse gas (GHG) emission world-wide must be reduced. This may be achieved by a number of methodologies which are suggested below.

(i) Energy conservation.
(ii) Measures to reduce the rate of deforestation.
(iii) Measures to discourage the use of wood from natural forests as fuel.
(iv) Replant fast growing trees for energy.
(v) Replace conventional fuels by renewables.

The first methodology suggested, i.e., energy conservation, seems to be the most implementable methodology among the others and, in fact, has been widely accepted as an efficient means to conserve energy. Energy conservation would the use of energy only when necessary and as efficiently as possible. Energy had been consumed by mankind for several thousand years for living and comfort. In the past 50 years, energy consumption by mankind has increased at a considerably sharp rate in the transport, industrial, business, and residential sectors. Energy had been used inefficiently due to the availability of cheap oil until 1973 when the first oil crisis occurred, followed by the second one in 1979. Oil prices sharply increased causing great concern to the governments of oil importing countries. Hence, it became necessary to reduce oil consumption by energy conservation measures and energy diversification.

Energy conservation measures have been adopted successfully in industrialized countries. Japan, where energy supply is largely dependent on imported energy, could be cited as one of the most successful countries in energy conservation. Energy efficiency has increased and losses have been reduced. R & D efforts to switch to renewable energies, like solar energy and wind, have been and are being carried out. Japan targets mainly at its industry and has been very successful. It is to be noted that the cogeneration of heat and power, which was a practice in the industry about a century ago and was halted when cheap power from distribution lines was available everywhere, has been revived with

success in industrialized countries during the last ten years, particularly after the second oil crisis. Unfortunately, cogeneration has not been as successful in developing countries due to lack of government measures and incentives, and due to low economic growth and underdeveloped industry.

Energy conservation measures have been successful not only in increasing the energy utilization efficiency, but have also resulted in reducing CO_2 emission rates. In Thailand, priority has been given to energy conservation in industry and buildings. Legislative measures were considered to be an effective instrument for energy conservation policy.

In this context, we shall discuss, in general, Thailand's policy in energy conservation that will affect technology transfer in two selected priorities, namely industrial cogeneration and energy efficient lighting for buildings.

2 THAILAND'S ENERGY CONSERVATION POLICY AND MEASURES

Thailand is a net energy importing country. Its dependence on imported energy, mainly petroleum, is about 45% of the country's energy demand. After the second oil crisis in 1979, Thailand suffered a major economic setback due to large expenditures on the import of oil. Since then, energy conservation has become a national policy in order to reduce Thailand's oil dependence. Public awareness has always been given priority by governments. Ministerial level committees have been set up and government owned mass media, such as television and radio, used to urge the public to use energy efficiently. This has been practiced for years without success due to, perhaps, the lack of knowledge about the technology of energy conservation among top decision makers, or perhaps due to the normal practice of the elected government to use government owned mass media for their own sake in seeking popularity for the next general election. The sole government energy agency, the Department of Energy Development and Promotion (the former National Energy Administration), has tried to convince past governments for almost six years to enforce a law on energy conservation. However, these efforts have not been successful. The failure was perhaps not only due to the lack of seriousness on the part of politicians or lack of political will but also to the fact that the content of the proposed law aimed to regulate and control the users of energy, particularly the industry and the owners of buildings, without positive measures or incentives to give assistance technically and financially to the private sector.

In 1991, during the period of the interim government of Anand Punyarachun, energy conservation was again stated as national policy. But this time, the government took it seriously and used legislative measures as an instrument for the implementation of its policy. The Prime Minister utilized his National Energy Policy Office to revise the previously proposed energy conservation law. The content of the law was changed to provide incentives to the private sector to conserve energy for their own benefit, which, in turn, will benefit the country in the long run. The government realized that,

besides housekeeping and retrofitting measures for energy utilization efficiency, capital investment for new equipment of higher energy efficiency would be necessary for the industry. Therefore, energy conservation funds were stated in one section of the law as a commitment from the government. The law was enacted within three months after the appointment of the working group for revision, in contrast with the six-year period of drafting the old version of the law. The Energy Conservation Act (ECA) was announced in the Royal Gazette in April 1992 and became effective since then, thanks to the Anand Government. It is believed that the new Act in conjunction with the current investment promotion act, and government policy on energy conservation would affect technology transfer. This is explained in the following sub-sections.

2.1 Investment policy and tax incentives

Before the ECA became effective in April 1992, the government had already introduced a policy to promote energy conservation by issuing a Finance Ministry announcement. This would reduce import duty of all proven energy conservation machinery and equipment from about 40 to 10%. The process of approval of energy conservation projects would be through a special committee set up by the Department of Energy Development and Promotion. The process has been slow and it has taken a long time for a project to even be approved. The ECA, through the energy conservation funds, would provide an alternative incentive by giving financial assistance to approved energy conservation projects equivalent to tax incentives. It is believed that it would eventually replace the tax incentive measures by the Finance Ministry. The ECA also provides incentives for investment in the energy conservation equipment industry.

2.2 Capital financing

At the moment, there is no special financing arrangement for energy conservation projects, provided directly by the government. However, these projects would be equally eligible to receive capital financing, with a low interest rate, from the government owned Industrial Finance Corporation of Thailand like other government approved projects. Capital financing is not a major problem for large firms which normally have good relations with the banks. In the future, it is hoped that the government would consider capital financing to small and medium industries.

2.3 Energy conservation related programmes

One of the most promising projects to cope with energy conservation, launched recently by the government, is Demand-side management (DSM). This project is aimed at increasing the electricity utilization efficiency of power consumers. The project cost is 4570 million baht (equivalent to US $183 million), for five years, and is aimed at saving 225 MW of the peak demand. The project will require technology transfer on high efficiency light bulbs, high efficiency electrical appliances, cogeneration equipment, etc.

3 INDUSTRIAL COGENERATION

This section focuses on technology transfer in the context of industrial cogeneration and assesses the barriers and opportunities involved in the process. Cogeneration, a simultaneous production of heat and power, is an effective means for increasing energy efficiency and reducing energy costs. Cogeneration has been employed by the US industry since the turn of the century and is being widely practised in Europe and elsewhere at present.

In Thailand, the first cogeneration system was installed at Teijin Polyester (Thailand) Ltd in 1974, a year after the first oil crisis. Teijin installed a 9 MW turbogenerator to generate steam and electric power in a cogeneration system. After the second oil crisis in 1979, the industry has become more concerned about reducing energy costs. Cogeneration has been increasingly applied in other industries, like pulp and paper, petrochemical, cement, etc.

3.1 Technology acquisition

Thailand's economy has grown steadily at a high rate of about 10% during the last four to five years, and will continue to grow, though at a slightly decreased rate (7–8%) in the next few years. This is largely due to the continued economic policy of every government to support and encourage investment in the country from both foreign and local investors, with attractive tax privileges from the Board of Investment (BOI) and without too much control. The private sector builds up their own capability in choices and transfer of technology. A study by the Thailand Development Research Institute on 'Development of Thailand's technological capability in industry' in 1989 reveals that large firms have developed their own acquisitive capability to the point where they can be on their own, without any assistance from government bodies.

As regards the cogeneration technology transfer, large private enterprises have capable technical and planning staff and access to information and development of cogeneration facilities in industrialized countries. They are capable of making their own study and their own on the decisions technology that they need to acquire. It can be said that there is no barrier for cogeneration technology acquisition for large firms. For small and medium enterprises, the opportunities for technology acquisition may be limited due to the lack of qualified staff. However, they can be assisted by the concerned government agencies or obtain a consultancy service from the concerned institutions. In Thailand, a number of distributors or representatives of foreign cogeneration facility companies from the US, European countries, Japan, and Australia are prepared to offer their services. Local companies, in association with foreign suppliers, are capable of supplying certain facilities or installation services.

In conclusion, it can be said that Thailand has no barriers to overcome to acquire cogeneration technology from foreign sources. Foreign producers of cogeneration facilities are willing to provide information and transfer technology to Thai companies. There are a lot of business opportunities for foreign firms in cogeneration and for the local industry to acquire cogeneration technology.

3.2 Technology absorption

Cogeneration technologies have been developed up to a stable state that the Thai industry is familiar with. The most widely used cogeneration technology in Thailand today is steam turbine cogeneration (topping cycle), where the steam produced from a boiler at a high pressure and temperature is used to run a steam turbogenerator and thus produces electric power. Steam is either extracted from the steam turbine at medium pressure or exhausted without condensing in order to be used in the process. The industry has no difficulty in absorbing this kind of cogeneration technology.

The second cogeneration technology that has become more popular is diesel cogeneration. Here, exhaust gas heat is recovered in a heat recovery boiler producing steam for process steam requirement. This technology can also be absorbed easily by the industry. In the technology transfer agreement, training for engineers and technicians is normally provided by the technology suppliers.

The third cogeneration technology is the gas turbine cogeneration with waste heat boilers. The basic cycle consists of a gas turbine, a heat recovery boiler, and a process heating load. Gas turbine cycles provide the opportunities to generate a large power output per unit of heat required in the process, relative to non-condensing steam turbine cogeneration cycles. In the past, due to the restriction of power production, the industry could not sell their excess power produced to the grid. Hence, gas turbine cogeneration was not suitable for Thai industry. At present, the government has revised the law concerning power production to allow private power producers from cogeneration to sell back excess power to the grid. Therefore, gas turbine cogeneration is likely to be of interest to the industry. As regards the absorption of technology, it is again not a problem for large enterprises. However, training courses offered by academic institutions, in association with experts from cogeneration suppliers, would help enhance the absorption of technologies for medium enterprises.

3.3 Technology adaptation and development

A number of engineering technologies, namely combustion, steam boilers, steam turbines, gas turbines, diesel engines, and heat recovery, constitute cogeneration technologies. Thailand has a good institutional capability in science and technology in these areas. However, since its industry is small, as compared to that of the industrialized countries, use of these technologies is limited and it is not economically feasible for the energy facility industry to set root in Thailand. Even today, the government provides attractive incentives for foreign investment and export and hence it is unlikely that cogeneration industry would be established in Thailand. However, part of the cogeneration facility technology like the steam boiler technology has been adapted and developed in Thailand. Frankly speaking, the state of adaptation and development in the industry is still at a beginning stage. Only low and medium pressure steam boilers could be manufactured in Thailand. Large firms prefer to deal with the supplier for a turnkey project. It is assessed that there is enough potential for development in the steam boiler industry in Thailand. This can be aided further through joint ventures undertaken by foreign technology suppliers and Thai partners. With investment incentives from the government and

capable manpower in engineering as well as low labour costs, it should make the investment beneficial. The market could be domestic; and yet export possible through the foreign partner distribution channel. The process of technology transfer could be done through the training and learning process of the company.

3.4 Examples of cogeneration facilities

A few examples of installed cogeneration facilities will be briefly described, including their characteristics and the process of acquisition

3.4.1 Teijin Polyester Company Limited (textile industry)

The company has installed a 9 MW steam turbine cogeneration facility which is now in operation. As the company is a Japanese joint venture, it has accessibility to cogeneration technology from the parent company in Japan. Hitachi, a Japanese company, is the technology supplier. The contract for purchase of cogeneration facilities includes the cost of know-how, engineers, installation, training of personnel, and commissioning.

3.4.2 National Petrochemical Corporation (petrochemical industry)

The company has installed three units of gas turbine cogeneration facilities of 24 MW each. It acquired equipment and technology from a German company in almost the same way as Teijin Polyester.

3.4.3 Punjapol Group of Companies (pulp and paper industry)

A 38 MW cogeneration system has been installed with the supply of technology and equipment from the Japanese company, Hitachi.

In conclusion, it has been noted that, in Thailand, there is a common practice that the terms and conditions of the supply of equipment and technology would be incorporated in the contract between suppliers and purchasers. The technology and know-how cost is normally included in the equipment cost. It is important that the contract signed would guarantee the purchasers of the smooth transfer of technology. After commissioning, the purchasers should then be able to operate the facility by themselves.

4 Energy efficient lighting

4.1 Introduction

In 1990, total electricity consumption in Thailand was 38 billion kWh, of which 20% or 7.6 billion kWh was used for lighting. The commercial sector consumed about 12 billion kWh (about 30%) and out of this 3.6 billion kWh was for lighting purposes. Hence, approximately 50% of electric power is consumed by the commercial sector for lighting. It is estimated that 20% of commercial sector lighting electricity consumption (780 million kWh) per year can be saved by using the DSM measure, like replacing ordinary light bulbs with energy efficient bulbs.

4.2 DSM

Thailand's five-year project on DSM has been launched by the government to support the energy conservation policy. The project is to be implemented by three power utilities with the collaboration of other energy related public organizations, academic institutes, and private sector organizations. The overall budget has been earmarked at 4.75 billion baht, of which about 1.8 billion will be spent on the DSM of commercial buildings for a period of five years. Half of 1.8 billion for the commercial buildings programme is allocated to efficient lighting.

For commercial buildings, the plan targets at two markets—commercial buildings larger than several thousand square metres in area and small commercial buildings primarily used as shops. According to the plan, large buildings will receive a comprehensive lighting retrofit with electronic ballasts, 32 W lamps, specular parabolic reflectors (fixtures), and automatic controls wherever appropriate. Small buildings, used mainly as shops, will be lit almost entirely by 40 W fluorescent tubes. The buildings would receive a package consisting of 32 W tubes and efficient magnetic ballasts to replace existing equipment. A special project to assess the costs for providing energy efficient lighting for all the temples, religious schools, and buildings in Thailand will be sanctioned. It should be possible to promote the use of efficient lighting which will include both the 32 W tubes with efficient magnetic ballasts and the compact fluorescent lamps. The latter will be used to replace the low efficiency incandescent lamps. It is estimated that about four to five million 32 W lamps, with either electronic or low loss magnetic ballasts, will replace the existing 40 W lamps in the project for the next five years.

4.3 R & D

A typical 40 W tube and ballast together consume about 50 W. An alternative is an efficient 32 W tube with a low loss magnetic ballast, which consumes only 36 W emitting light lumen equivalent to that of 40 W. With an electronic ballast, less than 33 W is consumed. The price of an electronic ballast is much higher than a magnetic ballast which, at present, is not attractive for users. However, it is envisaged that in the long run, R & D to reach low cost technology and mass production would bring down production costs and more will be used to replace the existing ones. For this reason, the Department of Energy Development and Promotion is now interested in developing electronic ballast and has sponsored a research project at the Chulalongkorn University. It is hoped that the knowledge of technical characteristics and design experience would then help in technology transfer to Thailand.

4.4 Technology transfer

As a result of the DSM programme, it is estimated that more than four million 32 W energy efficient fluorescent lamps will be used to replace the existing 40 W lamps. With the energy conservation policy and the incentives from energy conservation funds, it is anticipated that these lamps will be widely used in new buildings. It is only then that Thailand can initiate transfer of technologies regarding energy efficient fluorescent tubes, low loss magnetic ballasts, electronic ballasts, and compact fluorescent lamps.

4.4.1 Technology acquisition

The role of the government is to encourage investment for production of energy efficient equipment by offering incentives through the BOI. The private sector will seek opportunities to set up new lines of business. Since the Thai industry has developed to a mature state, most of them are able to make up their own minds in selecting technologies. The factors that they may consider essential for technology suppliers are: (i) past record of performance; (ii) well developed technologies; (iii) reasonable licensing fees; and (iv) friendly partnerships.

Barriers and opportunities

The market for fluorescent tubes in Thailand is sizeable. Approximately 35 million fluorescent tubes were sold in 1990. There are nine manufacturers of fluorescent tubes, of which Philips takes the largest share (35%) followed by Toshiba (30%). There will be no barrier to acquire energy efficient lighting technologies from industrialized countries. The acquisition process in the private sector involves contacting the technology suppliers and visiting the factories to negotiate terms. The project feasibility is made taking into account all incentives that will be given by BOI. If the project turns out to be economically feasible, then agreements can be signed without any government control.

4.4.2 Technology absorption

The lighting equipment industry set its roots in Thailand almost 20 years ago. Technologies have been transferred to Thailand through joint ventures and also to local manufacturers. New technologies can be absorbed without difficulty. Standard testing laboratories are available to help increase the quality of the products. The established linkages between academic institutions and industry have provided means for collaboration in technology transfer through training, consultancy, and R & D.

4.4.3 Technology adaptation and development

Thailand has developed its science and technology capability through formal education, R & D institutions, and other learning processes in the industry. Large industries have developed their own adaptive capability and set up R & D divisions. Technology adaptation and development could be done at the factory level, or through collaboration with universities, or R & D institutes.

5 CONCLUSION

Various parties have agreed that energy conservation measures, among others, would serve as a means for limiting CO_2 emissions. Developing countries, unlike industrialized ones, have not been successful in energy conservation. One barrier is the lack of technologies and knowledge of technology transfer. Thailand is fortunate that it has developed its industry to the state that technology transfer processes have been practised widely and are known to the public and the private sector. Thailand also

has enough science and technology capability and manpower for the transfer of technology. Its policy on energy conservation is clear. It has an energy conservation law as a master measure for implementation. Energy related organizations have been restructured and energy conservation projects like DSM have been launched.

Industrial cogeneration is now promoted by the government. Recently, there has been a policy change allowing industrial cogenerators to sell their excess power back to the grid, at a fair price, based on a long run marginal cost. As regards the transfer of cogeneration technology, the Thai industry, particularly large enterprises, is capable of acquiring technology and has enough capability in technology absorption. There is a good opportunity to promote the cogeneration market in Thailand, since the barrier prohibiting selling back of power to the grid has been removed. Energy efficient lighting is also being campaigned and promoted through a DSM project. High capital costs are the only barriers to be overcome in the promotion and utilization of energy efficient lighting equipment. However, technologies can be transferred to Thailand by setting up manufacturing plants to produce energy efficient lighting equipment, using investment incentives from the government.

Contributions from other member-countries

Technology development of cogeneration and energy saving lighting in China: an overview

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1 China's attitude about technology transfer

Environment and development are two major concerns of the international community. In the past, neglecting the environment in the course of industrialization, particularly the irrational exploitation and utilization of natural resources, has caused global environmental pollution and ecological degradation, posing a real threat to the survival and development of mankind. It is therefore an urgent and formidable task for all countries around the world to protect the environment and maintain sustainable development.

China considers that solutions to the two issues of environment and development call for extensive and effective international co-operation, since environmental protection needs to be a world-wide effort. However, international co-operation will only remain a mirage without a guarantee of funds and technology transfer. Environmental problems sometimes transcend national and regional boundaries and, therefore, a global approach is in the common interest of all countries and regions. It has been observed in the past that environment problems stemmed mainly from the excessive consumption of natural resources and massive discharge of pollutants by developed nations in the course of their industrialization. Even today, their consumption of natural resources and discharge of pollutants, whether in terms of total volume or per capita share, far exceeds that of developing countries. Therefore, they should assume the major responsibility for the deterioration of the global environment. On the other hand, they have greater economic strength and more sophisticated technologies for environmental protection. Hence, it is natural for them to undertake a greater obligation for its solution. They should provide developing countries with new and additional funds and transfer technologies of environmental protection, especially those commonly used in energy conversion sectors and end-use services, under concessional conditions to help the latter improve their environment and participate in the activities of global environmental protection. This would serve both their own interests and those of the developing countries as well.

The Chinese government has made environmental protection one of its basic state policies and has incorporated it into its national, economic, and social development strategies. On one hand, China

has obtained remarkable results in environmental protection by its own hard work. For example, over the past decade, or more, China has, in the course of reforms and opening up, maintained steady economic growth while averting a corresponding degradation of the environment, with even local investments. On the other hand, China is still willing to receive technology to accelerate its environment improvement.

2 COGENERATION

2.1 Current situation

Power generation in China and the contribution of cogeneration in 1990 is presented in Table 1. The total installed capacity of cogeneration presented in Table 1 includes only the units with single capacity over 6 MW, which account for 11.3% of the coal-fired units with the same capacity, while the coal-fired units with single capacity of over 6 MW takes up 87% of total coal-fired units.

According to the statistics, at present, the industrial heat consumption, based on cogeneration, amounts to 87%. The largest installed capacity of the thermal power station in operation is 850 MW. Cogene-ration and the district heating system in China are closely related. Cogeneration has remained the major source of the urban district heating. According to 1990 statistics, there are 89 cities with the district heating system in the northern part of China, where heating sources are necessarily required. These cities account for nearly 52% of the total cities in north China. The district heating area covers 0.19 billion m^2, accounting for 12% of total space heating areas.

2.2 Energy saving

2.2.1 Average fuel consumption in power generation

- Condensation units (≥ 200 MW)—394 gce (grams of coal equivalent)/kWh;
- Back-pressure units—200 gce/kWh; and
- Extraction units—350 gce/kWh.

Table 1. Power generation and cogeneration in China (1990)

Power generation	Capacity (GW)	Percentage
Total installed capacity	137.89	100
Hydro power	36.05	26
Thermal power	101.84	74
Cogeneration	10.00	—

Therefore, the cogeneration power plant consumes less fuel than the coal-fired power plant by 44–194 gce/kWh in electricity generation, which means that as many as 3–13 mt of coal have been saved and CO_2 emissions have been reduced by 1.6–6.8 mt of carbon in 1990.

2.2.2 Average energy consumption in heat generation

- Thermal power plants—40 kgce/GJ
- Decentralized small boilers—52–62 kgce/GJ

The above fuel consumption shows that the heating efficiency of the thermal power plant rises as high as 85%, while that of the decentralized small boiler is only 55–65%. In 1990, the total heat generation in China is approximately 565 PJ, in which cogeneration has saved 1.2–2.1 mt of coal and reduced 0.6–1.1 mt of CO_2 emissions (in carbon content) if the district heating rate is calculated as 12%.

2.3 Development prospects

In some industrially developed countries, cogeneration accounts for a high percentage of thermal power generation. For example, the percentage is as high as 40% in the former USSR. In comparison, development of cogeneration in China is slow. But, to realize the objectives of energy saving and environmental protection and meet the growing requirements of industrial production and demand of people, cogeneration is expected to find wider application in the future.

China's energy sectors have set a preliminary energy-saving target for 2000 AD. By then, the specific fuel consumption of electricity supply would drop to 360–370 gce/kWh from the current level of 427 gce/kWh. It is stipulated that the newly built units will consume no more than 330 gce/kWh of fuel for electricity supply and no more than 270–280 gce/kWh of fuel for heat generation. It is also estimated that during the period 1990–2000, a total new capacity of 90 GW of thermal power plants is expected to be built in order to realize the objective of energy saving with a high efficiency of cogeneration, and contribute a larger share, over the existing level of 10%.

Coal represents more than 85% of the fuel for thermal power generation. About 0.29 bt of coal are fired every year, producing emissions of CO_2, SO_2, NO_x, smoke, and dust, and poses a serious threat to the environment. With the future development of the electrical power industry, coal consumption will definitely increase. Hence, it is a necessary and important requirement that the efficiency of power generation be raised to reduce coal consumption, so as to protect the environment.

At present, there are 240 000 industrial boilers in China and heat generation meets about 90% of the industrial heat demand. So, the replacement of the decentralized small boilers with large thermal power plants is yet to be achieved. The district heating rate in North China is relatively low (12%), and the hot water supply is practically nil. With the improvement of the living standards of the people, there will be an increase in the demand for heat.

2.4 Measures and policies

Proper measures and policies have been adopted to encourage the development of cogeneration.

(i) District heating systems have been encouraged to expand rapidly in urban areas, which is proposed in the 'Environmental Protection Law' of the People's Republic of China.
(ii) Cogeneration and district heating systems would be developed, stressed by the 'Provisional Regulation for Energy Saving Management'.
(iii) High parameter and large capacity units, including cogeneration ones, should be strongly taken into consideration while making future electricity development plans.
(iv) Operation of small capacity, medium, and low pressure condensation units, in service for too long, should be phased out in a planned manner. For those units which cannot be scrapped at present, reforming and renovation will have to be carried out to transform them into extraction or back pressure units. Some of the concrete measures to be adopted can be listed as follows—first, all the total 20 GW capacity of medium and low pressure units should be phased out firmly, and part of them can be permitted to be shifted to the units for heat supply. Second, for the total 60 GW capacity of high pressure units including the units of 100, 125, 200, and 300 MW, special renovation should also be made with emphasis on 200 MW units, of which there are still 110 units with fuel consumption as high as 410 gce/kWh.
(v) Studies on the trigeneration of gas, thermal power, and electrical power to be conducted in the near future.
(vi) Management of existing power grids would be enhanced and insulation of pipe networks and valves would be improved to prevent leakage of heat energy.
(vii) Power grids should be economically modelled, e.g., in regional power plants; coal supply could be shifted from small-sized power plants to large-sized ones to enable full operation.

If all the above policies and measures are implemented, the target of reducing fuel consumption per kWh of electricity supply could be realized. And, if the total capacity of thermal power stations is 100 GW, about 60 mtce of energy could be saved, resulting in removal of 44 mt of CO_2 (carbon), a large amount of NO_x, and dust.

2.5 Problems to be solved

To develop high parameters and large capacity units, it is quite important and necessary to learn the latest design and manufacturing techniques in the world and have technology transferred from the developed countries, either gratis or on concessional terms.

Transformation of the small capacity, medium, and low pressure units into cogeneration units would need an investment cost of 2000 Yuan/kW, which is equivalent to the current cost of building a large unit. If total capacity of 16 GW is to be reformed, an input of 32 billion Yuan is needed. But, the annual investment for technical renovation is even less than 0.5 billion Yuan. It should open more

channels to collect necessary funds to ease the shortage and lay out appropriate policies for investment, price, tax, and foreign trade to ensure this process.

Investment
In the existing investment composition of the electricity industry, the state's investment and loans, fund raising, and funds raised by oneself are the major channels, accounting for 17.4, 17, and 17.1% respectively in recent years. Since the beginning of economic reforms in the late 1970s, the investment pattern, has shifted from state investments and loans to multiple sources. In particular, the investment policies for fund raising and funds raised by oneself have encouraged regions and enterprises where serious electricity shortages exist. This can be attributed to policies that stipulate clearly 'who invests, who benefits' which guarantee sufficient power supply to investors as also better profits.

Price
The price of heat supply from cogeneration stations is too low. For instance, loss of profits from selling heat was about US $0.36/GJ in the recent years. Losses suffered by the power industry hinder the expansion of cogeneration. It is necessary to adjust the price rationally, through price reforms, coupled with economic reforms, to encourage the development of cogeneration.

Tax
In order to ease the situation of fund shortage, a special item of 'funds for key energy and transport construction' was proposed in 1983. The funds raised have to be used specifically for the development of the energy and transport sectors. Furthermore, a survey report on the situation of urban district heating, submitted by a group of domestic environmental experts, recently suggested that smoke tax for decentralized small boilers in urban areas might be stipulated, in order to restrict the development of small-sized boilers. The money gained from the smoke tax would be taken as special construction funds for cogeneration development.

Foreign funds
Since economic reforms and the opening up to the world, the policy of absorbing foreign funds for domestic economic development has been actively implemented in China. More flexible approaches will be adopted for perfecting the investment environment, providing more convenient conditions and legal guarantees to foreign investors, and finally attracting foreign funds. The foreign investment will be directed to the major fields of technical innovation in infrastructure, in basic industries, and capital- and technology-intensive industries as well. In the past, a lot of foreign investment was oriented to the development of cogeneration; foreign funds shared about 13.6% of the total each year.

The stable heat load is considered to be a very important factor to develop cogeneration and bring about economic and environmental benefits. At present, the industrial production lay-out and urban construction are less unified and co-ordinated, thus resulting in decentralized heat load and unstable

demand. Therefore, it is necessary to step up the cogeneration management, unify the development plan, and standardize the construction.

3 LIGHTING

3.1 Current situation

With the rapid development of the industrial and agricultural production, urban construction, and tourism as well as the improvement of people's housing and public facilities, there has been a substantial increase in electrical power for lighting. Since 1985, the annual growth rate has reached 15%. In 1990, the electricity consumption in lighting was about 80 TWh, accounting for 13% of the total electricity consumption. It is roughly estimated that around 23 TWh of electricity was consumed for lighting purposes by residential sectors and 57 TWh by other sectors. Based on this fact, and assumptions of electricity consumption in the sectors of industry, transport, commerce, service, etc., it was derived that lighting load accounts for approximately 40–45% of the total peak load. In that case, energy efficiency improvement in lighting is one of the important measures to ease the demand for power supply by reducing peak load.

In 1990, China's production of electric bulbs was about 2.1 billion, while the incandescent bulb output was 1.85 billion, amounting to 88% of total production. The production output of the common fluorescent lamp was approximately 0.2 billion, while that of high pressure mercury lamps, high pressure sodium lamps, and others was 200 million pieces totally.

3.2 Energy saving

The power rate of the most powerful incandescent lamp is 40–75 W. The incandescent lamp is known for its low efficiency and high electricity consumption. The fluorescent lamp and the compact energy saving fluorescent (i.e., the trichromatic) lamp, which are expected to replace the incandescent lamp, have great energy saving potential.

Now, the fluorescent lamp made in China consumes only about 1/2–1/3 of the electricity needed for the incandescent lamp and provides the same illumination. But its wide application is still limited owing to certain reasons. The comparatively big size is not convenient for use while its low colouring index does not satisfy special requirements in some sectors. It also has a low lifetime. Moreover, its prices are high when compared to that of the incandescent lamp.

The trichromatic lamp is the latest product with a lighting efficiency that is supposed to be four to seven times that of the incandescent lamp, 1.2–2.3 times higher than that of the fluorescent lamp, lasts longer, is of a convenient size, and has a high colouring index. If an incandescent lamp with 75 W is replaced by a trichromatic lamp with 16 W power consumption, assuming the average lighting hours to be 1800 hours per year, then we can calculate that every year about 10.5 TWh are expected to be saved. The price of a trichromatic lamp is around 26 Yuan a piece, and its service life is

3000 hours. The average service life of the incandescent lamp is only 1000 hours but it is priced rather low at 0.7 Yuan per piece. The analysis and comparison show that the application of the trichromatic lamp offers greater energy saving, and many other benefits.

3.3 Development plan

As stated above, we can see the high energy saving potential of the trichromatic lamp, which is expected to substitute the current incandescent lamp. By 2000 AD, if every household would have at least one trichromatic lamp, and enterprises and administrative organizations would also take action to use more of these lamps for energy saving, it is estimated that there will be 0.5–0.7 billion trichromatic lamps replacing the incandescent lamps and about 50–70 TWh will be saved which would, in turn, result in the saving of 20 mt of coal and 10 mt of CO_2 (in carbon content).

3.4 Measures and policies

An increase in investments is required to establish and improve the industrial production system for the trichromatic lamp so as to increase the production and ensure supply. In order to raise more funds and catch up with the world's advanced levels, importing of foreign investment and advanced technologies have to be encouraged according to policies concerning foreign investment. For the Chinese industry and enterprises, foreign funds with concessional conditions, e.g., low interests and long payback periods, are given priority. Now, certain advanced production lines of energy saving lamps have been imported by Chinese factories. For instance, more than ten kinds of trichromatic lamps are being manufactured by the Beijing Electron Tube Plant using imported production lines. The new products can generally save around 80% electricity when compared to incandescent bulbs.

More attention has to be paid to the research work of the trichromatic lamp. At present, the poor quality poses a serious handicap to its usage. The actual service life is about 1000 hours, only 1/3 of the normative service. Therefore, the users get no economic benefits. To improve the quality, the emphasis has to be placed on the import and introduction of the advanced technological processes and production lines. The service life of the trichromatic lamp, e.g., made by Philips can become 8000–10 000 hours.

There is the need for publicity and education in order to raise the public awareness of energy saving, and initiatives to promote the application of the trichromatic lamp must also be examined.

Bibliography

1 State Statistical Bureau of China. 1991. *Statistical Yearbook of China (1991)*. Beijing: Press of Chinese Statistics.
2 State Statistical Bureau of China. 1992. *Energy Statistical Yearbook of China (1991)*. Beijing: Press of Chinese Statistics.
3 Wang Zhenming. 1991. Energy conservation and cogeneration. Internal research report.
4 Wu Liangsheng *et al.* 1992. Development strategy of energy-saving lamp industry in China. *Quantitative and Technical Economics*. 8(4).

Country policy affecting technology transfer in Iran

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1 INTRODUCTION

Considering the fact that the emission of the most important gas in the greenhouse effect (CO_2) is unavoidable due to the use of fossil fuels, the best way of reducing this gas may lie in a more efficient use of energy on one hand, and an increase in the consumption of CO_2 on the other. In this respect, it was decided at the Bellagio Conference in April 1992 that every country should study one or more technological methods to reduce greenhouse gases (GHGs). It was also decided that the problem of afforestation and lighting which the government officials are more concerned about would be looked into by the Iranian government. The former will help in sequestration of carbon. The latter, when implemented effectively, will reduce the consumption of fossil fuels and the release of more CO_2 as well.

2 LIGHTING

The demand for electricity has been growing due to the increase in population and use of electricity per head. In this respect, electricity generation is expected to reach 28 000 MW during the First and Second Five Year Plans—an addition of 11 000 MW to the present capacity of electric generation in Iran.

Considering the present efficiency of the power generation units, this requires 50 000 MW of heat energy and leads to 33 mt of carbon in the form of CO_2 emissions. In addition to this heavy consumption of fuels, the cost of electricity has also to be considered. At present, the Iranian Government subsidizes electricity, at the rate of 30 rials for each kWh. Therefore, it should consider the economic aspects of electricity generation, which has to be produced with minimum cost and maximum benefit. For this goal, different technical and managerial methods have been studied. The summary of these suggestions and theories will be outlined later in the paper.

2.1 Reduction in the loss of energy consumption in equipment

Lighting is the main component of electrical consumption in Iran and more efficient use can play an important role in improving the electrical industry. With the present technological progress, a variety of bell-shaped electric lamps have been developed, which are similar to fluorescent lights with a difference that, by concentrating the electric circuit, it can be replaced with the traditional lamps. Considering the efficiency of these bulbs compared to the traditional ones, the quality of the network can be improve. However, its high cost and its economic aspects must be studied. The saving in each MW is equal to 0.7 mtoe. Saving in each mtoe is equivalent to 0.66 mtoc (in the form of CO_2). If we reduce the energy used for lighting by 30%, the reduction in use of fossil fuels will be 27% which results in 7.7 mt less carbon in the air.

For this programme, we do not need new laws or specific actions. All that is required is a government decision to use this technology and determine the appropriate budget to subsidize the purchase of these bulbs. The only difficulty lies in the replacement of the existing bulbs with the new ones considering their prices and their lifespan when compared to the traditional bulbs. The reduction in consumption, which will lower the amount of investment needed for electricity generation, will justify subsidizing the price of the bulbs to the consumer. It has been forecasted that the power generation will reach 22 500 MW by 1993, and 35 000 MW by 1998. However, due to difficulties, it does not seem that all the projects will finish on time. Presently, a generator of 5000 MW productivity is under construction, and hopefully, will be added to the network on time.

3 ELECTRIC INDUSTRY IN IRAN

3.1 Past, present, and future

The capacity of the power generation units reached 14 000 MW in 1988, a growth of 6.5% between 1979 and 1988. The status of the power generation units controlled by the Ministry of Energy are shown in Table 1. These units mostly use fossil fuels, and therefore, the Ministry is the largest consumer of the fossil fuels. Hence, it is responsible for the largest emission of GHGs. Table 2 shows the consumption of different fuels.

Generation and transmission of electric energy has been expanding regardless of its cost of operation. Among the factors that have contributed to the failures, which the Ministry of Energy has met by the growing demand for electricity, are:

(i) rapid growth;
(ii) financial constraints due to dependence on foreign technology, as large sums of foreign exchange allocations are necessary;
(iii) low profits;
(iv) inability to secure fuels on time for the power generation units, which has prevented the use of these units in the network; and

Table 1. Electricity generation in Iran (1979–1989)

Subject	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Maximum consumption need (MW)	3744	4390	4269	—[a]	5704	6605	7370	7746	8289	8298	8985
Maximum assigned load (MW)	3621	4143	4229	4923	5582	6333	6606	7464	7743	7762	8911
Operated power cut-off (MW)	123	247	40	—[a]	122	272	764	282	546	536	75[b]
Needed energy (million kWh)	—[a]	—[a]	22 644	26 407	30 813	34 568	37 722	40 385	43 577	—[a]	—[a]
Energy supplied (million kWh)	19 441	19 880	22 406	26 333	30 509	34 094	36 720	39 045	42 554	43 775	39 956

[a] Reliable information not available. [b] Actual cut-off in this year has been 1153 MW.

(v) other difficulties like social conditions, decentralization of decision making, and the climatic conditions of the country.

4 Forests

Forests in Iran are situated in two distinct regions of northern and western Iran. Forests in the North cover 1.9 million acres. From this, 1.3 million acres are allocated to industrial purposes (ready for industrial activities) and the rest, 0.6 million acres, are semi-demolished forests. Forests in the West cover 3.5 million acres. Most of them are considered to be semi-demolished.

Every year, 2 mm^3 of wood is acquired from these forests. Another 2 mm^3 is also obtained from woody trees and from gardens. Since the total need of the country for wood is 8 mm^3, the country faces a 50% shortage. The Food and Agriculture Organization has estimated the per capita need of wood for developing countries at 0.4 m^3. According to this estimate, the need of Iran should be 22 mm^3. Obviously there is a big gap between the actual need and estimated figure.

Table 2. Use of fuels in power plants under the management of the Ministry of Energy (1979–1989)

Fuel	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Gas oil (million litres)	1398	983	948	1010	1289	1622	2191	1642	1480	1517	1259
Residual oil (million litres)	1064	1473	1900	1947	2618	3183	3568	4150	3559	3839	4100
Natural gas (mm^3)	2335	2278	2360	3177	3621	3885	3993	3856	5451	5730	6863

The general goals of the Ministry of Forestry in Iran are as follows:

(i) protecting the forests;
(ii) reviving the forests;
(iii) proper utilization; and
(iv) relative self-sufficiency in providing wood products.

In the past 30 years, the government had planned for the afforestation of 630 000 hectares and the growth of forest plantations (52 000 hectares) in the North, in addition to 2900 hectares in other areas. Most of this has been implemented. This has compensated, in a small proportion, for the damage to the forests. The following steps have to be considered with respect to renewing the forests.

(i) Afforestation of 50 000 hectares per year in the North to revive the 600 000 hectares of destroyed forests in this region.
(ii) Afforestation of 50 000 hectares per year in the western region to replace 3.5 mha of forests destroyed there.
(iii) Afforestation of 11 000 hectares per year in other regions to provide wood.

The budget for reviving the forests: planting forests—29 000 million rials, foresting—8366 million rials, and forest engineering—5590 million rials

The main causes of vegetation destruction in Iran are the movement of sand in the areas with winds at high speeds; loss of pastures due to uncontrolled grazing, specially by goats; illegal use of forests and land for other agricultural purposes; wrong approaches to the utilization of water leading to the lowering of the underground water level, and, consequently, to forest dryness; uncontrolled expansion of dry farming; and natural, regional, and industrial causes.

5 Technology transfer

Transfer of technology can be divided into four stages—development, adaptation, absorption, and acquisition. However, Iran has considerable experience with respect to forest plantation and creation of forests with the help of irrigation. For many years, Iran has developed forests around big cities such as Tehran, and planted special plants around deserts to stop the movement of sand and add to the green areas. Hence, transfer of technology is not really required. What is necessary is the establishment of more educational centres for training the required personal in forest plantation and natural resource engineering. Other countries could also benefit from Iran's experience in these fields. However, for the absorption, adaptation, and development of technology, research into the types of vegetation, adaptable to the Iranian climatic conditions and the improvement of local vegetation, is necessary.

As regards forest plantation and revival, it has been noticed that financial assistance from international foreign sources, such as World Bank, and from the private sector is necessary. The Iranian

Ministry of Agriculture, Ministry of Natural Resources, and the *Jahad* have extensive plans for the development of forests in the country. The most important tasks and the relevant legislations that need to be pursued are given below.

(i) Establishment of an appropriate and adequate structure for the projects with the help of legislations in the parliament.
(ii) Establishing a balance between cattle and the pastures available for grazing (by purchasing excess cattle).
(iii) Executing programmes for the development of pasture projects.
(iv) Execution of programmes for reviving the pastures to achieve additional potential for production of wood.
(v) Co-ordination for the creation of a balance among cattle, animal feed, and pasture land.
(vi) Executing programmes for the expansion of animal feed and other similar feed in the country, and for the planting of industrial trees.

Role of technology transfer in abating greenhouse gas emissions: the case of Sri Lanka

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1 Introduction

1.1 The energy scenario

In Sri Lanka, 6.6 mtoe of total energy was supplied in 1989. The share of commercial energy was 1.9 mtoe or 29%. The balance 71% was from fuelwood. Consumption of commercial energy in 1989 was divided between transport (55%), household (20%), industry (18%), agriculture (2%), and others (4%).

Hydro-electric power remains the major source of electricity, accounting for 2900 GWh in 1992. Thermal generation accounts for about five per cent only. The impact, associated with the generation of hydro-electric power is linked to the construction of dams and reservoirs. At present, no major impact can be expected from the thermal sources, in view of its limited use. However, environmental safeguards will be required when thermal plants are continuously operated, or when new plants are planned. It is evident that the transportation sector is the largest consumer of commercial energy. The principle environmental impact associated with transportation is air pollution.

The National Environmental Act (amendment) introduced in 1980, gives the Central Environmental Authority (CEA), among other powers, the functions of the control of emissions, disposal of wastes into the environment, and the subjection of development activities to environmental impact assessment at the project planning stage. The former has been operational through the National Environmental (protection and quality) Regulation 1 (1992).

1.2 Prevalent policies that affect the process of technology transfer

The Board of Investment (BOI) of Sri Lanka has been created recently, and is the sole authority for promoting and approving investment in Sri Lanka. It functions as the 'one stop shop' service centre, catering to every need of the investor. It administers three free trade zones established for investors. In addition, an attractive package of incentives is offered for export oriented investments. Approval procedures have been evolved, shorn of bureaucratic delays, to the point where it has become simple and transparent.

An attractive package of incentives, with no restrictions on repatriation of funds and dividends, and tax holidays up to 15 years and more, has been introduced. The other significant developments are:

- liberalized policies of import/export;
- a well developed infrastructure and BOI's experience of over 14 years in the operation of export processing zones;
- the high literacy of the workforce;
- simplified approval procedures; and
- free operation of foreign bank accounts, with 100% foreign ownership, or joint ventures with local investors.

The primary objective is to attract foreign investors and provide them with maximum opportunities for investment, trade, and joint ventures. It would be required to arrange one-to-one meetings and visits to the export processing zones, and apprise them open to the areas of foreign investment. It is our view that Sri Lanka, as yet, has no restrictions as far as the process of technology transfer is concerned. It is open to any type of technology, provided that the industries promote the use of the unemployed human resources of the country, instead of making use of machines, and thus reduce labour content.

2 HISTORICAL PERSPECTIVE—SINCE 1982

In 1982, Dr Mohan Munasinghe of the World Bank was on an assignment as Energy Advisor to the President of Sri Lanka for a two-year period. He initiated an integrated energy planning framework so that inter-ministerial co-ordination could take place in all energy related matters. The Ministry of Power and Energy was created, and national energy planning involved the Ministries dealing with forestry, transport, power, petroleum, and other industries. Unfortunately, the task forces which were created has been dispensed with, and action has to be taken to revive them.

The present government's intentions regarding energy conservation led to the creation of the State Ministry of Conservation in 1991. It is fortunate that the Director of this Ministry of Conservation is the past President of the Sri Lanka Energy Managers Association (SLEMA). It is expected that the government will be able to give more incentives for energy conservation matters. Part of the energy conservation fund is presently used for preparation of documents to be issued to the public at exhibitions on conservation. Regular television and radio programmes are held under the auspices of this Ministry. In the domestic sector, conservation measures are under consideration. The measures include those that have been described in the following paragraphs..

For cooking, improved cookstoves are being promoted through the Ministry of Power and Energy. Use of gas, in preference to electricity, is being promoted by pricing. Use of vessels with good

conducting bottoms in cookers, use of rice cookers which are fully insulated, and use of pressure cookers which reduce energy consumption, are being promoted.

The drive is also on to introduce efficient lighting. A separate report on the use of efficient lights is outlined later on in this paper. It is estimated, that about 80 MW (1/10 of the peak power) of power is used by irons in all the houses daily. An effective change in the material, to that of the non-iron type, could save this load and reduce the energy use. Action is being taken to work with the Institute of Architecture in planning and designing houses in order to enable them to use natural lighting. Wherever air-conditioning is used, the house has to be designed to minimize losses, and to prevent direct solar radiation into the house. Domestic solar water heaters have to be promoted through tax incentives.

At present, energy management is practised in the industry and almost all the large industries have an Efficacy Engineer or a Energy Manager in their staff. A good part of the industrial load comes from the hotel industry. Regular seminars and training of boiler operators are held annually to promote this energy conservation activity by SLEMA itself with support from the Ministry. In agriculture, four wheel and two wheel tractors have been introduced in the recent past.

Research has indicated that the energy used by four wheel tractors for ploughing is very inefficient. Deep plugging is not really required, and a two wheel tractor may be a better compromise. Solar powered battery weed cutting devices and ploughing machines are being proposed by the agricultural research institutes. Again, the sea around Sri Lanka is intensively tapped for fish. Energy efficient boats need to be introduced for this activity. Energy efficient refrigeration also has to be introduced in the processing of fish.

Several steps have been taken to improve the viability of public sector industries. Opening up of opportunities, to engage in joint ventures with large foreign companies, is one of them. Collaboration with Japan, Germany, Australia, and Britain are some examples. A presidential commission on privatization has completed a study on 21 public enterprises with the assistance of World Bank. It has categorized enterprises into three—those that had to be closed those which can be restructured within a short period, either financially or technically; and those which have to be privatized.

The balanced development of energy planning skills, both at the management and the technical level, is important. The underlying theme should be self-reliance in energy planning, because the final responsibility of the integrated national energy planning should rest on the local staff and the policy makers. Although, in many cases, it may be necessary to rely on foreign experts or consultants to initiate the process and play an advisory role, the training of local counterparts and the goal of eventual transition to complete the national staffing should be given high priority. At the same time, since both technical and economic knowledge in the energy area tends to change rapidly, energy planners should have good up-to-date library and documentation facilities as well as ready access to international conferences, training courses, and meetings. Finally, if salary levels are inadequate, it will be rather difficult to recruit and retain personnel with energy related skills. Past experience has shown that a large number of experienced professionals have left for greener pastures in other parts of the world, while some have been taken away by the consultants or loan-giving agencies.

2.1 Industrial policy

In 1990, initiatives were taken with regard to the implementation of the new industrial policy introduced by the Ministry of Industries, Science, and Technology. The Greater Colombo Economic Commission and the Foreign Investment Advisory Committee were merged in January 1990, to form one window in order to facilitate the entry of foreign investments. Approval procedures were also simplified. In January 1990, foreign investors were permitted to own 40% of the shares of existing companies without any approval in response. Multinational corporations now seem to prefer to invest in countries with well educated and technically qualified workforce. More sophisticated industrial production requires skilled labour. Therefore, the availability and cost of skilled labour become very significant. Since we have the disadvantage of a small domestic market, internal insecurity, and perceived country risk, our ability to attract a higher level of foreign investment would depend on the development of our infrastructure and improvement in the quality of our labour.

A new industrial strategy was introduced in 1990 by the Ministry of Industries with a view to restructure the overall domestic industrial policy. It intends to (i) transform the import substituting industry to an export oriented industry; (ii) provide greater employment and income opportunities; (iii) diversify the economy and strengthen the balance of payments; and (iv) ensure more equitable distribution of income and wealth. The strategy also includes policy measures aimed at mobilizing resources for investment and export encouraging foreign and local investment; reforming public enterprises; promoting a competitive environment; establishing linkages between large and small industries; promoting research, training, and marketing; and removing administrative obstacles to investment, production, and exports. The promotion of research and training can play an important role on technology transfer and conservation.

2.2 Changes in the foreign investment policy in 1992

Changes in exchange control regulations to all foreigners and foreign agencies to buy up certain Sri Lankan ventures, has been gazetted. The government will permit non-residents and approved foreign funds and corporate bodies to purchase shares in Sri Lankan companies up to 100% of the issued capital, subject to certain restrictions (if the capital is more than one million US dollars). The 100% transfer tax, composed on the transfer of assets between nationals and non-residents, has also been already abolished.

2.3 Conclusion

Forcing a developing country, to reduce emission of greenhouse gases (GHGs) can be acceptable only if the necessary funds for capital investments and the technology transfer for more energy efficient devices are available. Use of alternate sources of energy must be promoted. Studies, sponsored by the United States Agency for International Development through the Tata Energy Research Institute, show encouraging signs for proper transfer of technology in the future, and that funds will be available to reach the targets. One also feels that learning to live in harmony with Nature rather than work

against it is the best solution, only then our life will be peaceful. Nature will definitely look after itself We should try and disturb it to the minimum by reducing our wants.

3 Case-study of energy efficient lighting systems in Sri Lanka

3.1 The background

Sri Lanka's national electricity grid provides all the electricity requirements in the country, except in a few very remote areas where, if at all, small generating sets are being used for a few hours of the day. The system demand profile, given in Figure 1, shows a very high peak during the evening hours from 1800 to 2000 hours. The system load factor for 1991 was 56% which has been recently varying between 54 and 56%. The Ceylon Electricity Board (CEB) is optimistic of achieving a higher load factor of 58% by the year 1997.

The Sri Lankan power system is predominantly hydro-electric, through which the entire demand as of now can be met from hydro-electricity in an average rainfall year. The poor load factor is not of

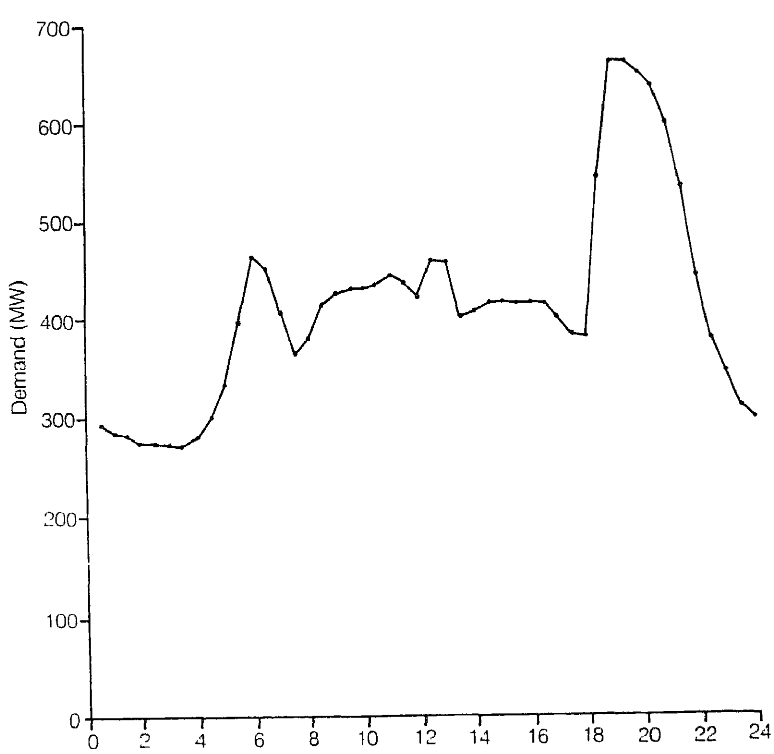


Figure 1. Sri Lankan power system—half-hourly demand profile at generation (February 1992)—not adjusted for the disconnected northern load.

significance, when generating capacity is considered. The hydro-electric system has over 80% reserve margin. The sharp peak in the evening is of significance only for the transmission and distribution system, and the sub-stations in which certain links are overloaded during the peak. However, high reserve margins will not prevail for long, as the generating system is presently transforming from a predominantly hydro-electric system to a mixed hydro-thermal system. Any savings, in peak time capacity requirements, would certainly be beneficial from the year 1998.

However, the sharp lighting peak in the evening causes a heavy demand for energy. It can be clearly identified that the evening peak demand is almost entirely due to household lighting. The street lighting and commercial buildings need not account for more than 10% of the 300 MW evening lighting peak demand. With the rapid rural electrification programme of the government in which most new consumers are from the household sector, the system load factor and the peak time energy consumption can only be expected to worsen.

The time-of-the-day tariff introduced six years ago is now available to medium and large industrial and commercial consumers, as well as for hotels. This tariff carries a unit charge of double the regular rate between 6 and 9 p.m. and rebate for energy used during off-peak hours. While the exact benefits of the time-of-the-day tariff for large consumers are yet to be evaluated, introduction of such a tariff for households has not been considered yet.

Therefore, the only alternative to achieve the desired improvement in the system load factor, and to bring about a reduction in the household consumption of electricity, will be to improve the efficiency of the lighting systems used in the households. This paper describes the efforts made so far towards this objective and their results, together with details of the costs and benefits of a possible state sponsored or private sector funded popularization programme for efficient lighting systems.

3.2 The composition of the load curve

The electric system demand curve shows a sharp peak, approximately between 6 and 9 p.m. on all days of the week On a typical weekday in February 1992 (Figure 1), the system demand increased from 380 MW at 6 p.m. to a peak of 680 MW at 7.30 p.m. Figure 1 also shows the half-hourly peak but the instantaneous peak may be higher.

In the absence of a specific study at the consumer level on the composition of the demand curve, it would be reasonable to assume that the total evening lighting load in the country is 300 MW. If an allowance is made for the industries finishing their working shift at 6 p.m., this estimate can be higher. Similarly, an unknown portion of the evening peak would be taken up by television sets. With the exception of street lamps, the lighting load operates for about three hours a day. Therefore, the corresponding energy use will be 300 MW × 3 hours × 365 days = 329 GWh/ year. There is also the daytime lighting load, especially in commercial buildings, which has not been estimated.

The type of lamp that causes the excess lighting demand is also not known. An estimate may be made, by assuming that at least three incandescent lamps of 40 W each would be operated in each household at peak time, which amounts to a share of 120 MW of the evening demand, from the one

million households that have been electrified. There is a widespread belief that this share is higher, reaching at least 200 MW.

Owing to financial constraints, households that are newly electrified would always prefer incandescent lamps. These will be partially replaced with fluorescent fittings depending on the level of the consumer's awareness on energy conservation potential and his ability to pay the higher costs required. The quality of conventional fluorescent fittings available in the Sri Lankan market is not satisfactory, with excessive losses occurring in the ballast. The fluorescent bulbs used also do not generally provide the best luminous efficacy of the conventional bulbs. The lamps used in the commercial buildings and in industries during all hours of the day are not estimated here because a proposed programme for popularization need not give incentives to such consumers. The exception will be public institutions such as hospitals and government offices, which remain under the direct control of the government.

3.3 Previous efforts

The efforts by the government, state agencies, and non-governmental organizations in the improvement of the efficiency of lighting systems began in the late 1970s with the national electric power utility—the Ceylon Electricity Board, conducting publicity on energy efficient lighting systems. However, the serious efforts for the widespread use of fluorescent lamps began only in the mid-1980s, with the sharp escalation of electricity tariffs.

It would be confidently expressed that large commercial buildings and hotels in Sri Lanka now use fluorescent lamps to the best of their ability and limit. The area that needs special concentration therefore is the household sector. Households use nearly 40% of the electricity consumed in the country, a significantly high share for any country. Industries consume yet another 40% and the remainder is taken up by the hotels, commercial buildings, and street lighting.

3.4 Regulatory measures

The major issues in the regulatory framework for energy efficient lighting systems are:

(i) the absence of efficacy standards for lamps that are locally manufactured and those imported into the country;
(ii) the poor enforcement of the quality standards;
(iii) the absence of national guidelines/standards for the levels and quality of illumination within buildings; and
(iv) the taxes and duties applicable to lamps.

There is an established local industry for the manufacture of incandescent lamps. However, there are no standards for their luminous efficacy and overall energy efficiency. There is no local industry manufacturing fluorescent lamps for the local market (there is at least one export oriented venture). Thus all such lamps and the accessories are imported. The assembly of fluorescent lamps is done

locally. The import of fluorescent lamps, of poor luminous efficacy, low lifetime, and ballasts of poor quality and audible noise levels, are widespread. Further, the assembled fittings do not consist of a power factor correction capacitor which has an adverse effect on the consumers' and the system's power factor, as well as on the luminous efficacy of the lamp. Existing standards do not cover the luminous output of lamps or the energy efficiency of the ballast.

The enforcement of quality standards in terms of the electrical characteristics of the lamps and fittings requires to be strengthened. The initial requirement is to enforce the existing national standards on all locally manufactured and imported lamps, accessories, and assemblies. The present practice is for the lamps and lamp fittings to carry the approval from the Standards Institution (SI), if they confirm to the relevant Sri Lankan standards. The majority of lamps and lamp fittings available in the market, however, do not carry the approval of the SI.

The level of awareness among the general public, engineers, and architects about appropriate illumination levels for different tasks, optimization of lighting in the day, and the design of buildings for energy efficiency is low. An awareness campaign supported by informative material, seminars, training courses, and an award scheme have been suggested by SLEMA and it is hoped that the Sri Lanka Institute of Architects will participate in this campaign. A pre-requisite for such a programme would be the national standards/guidelines for efficient illumination systems for buildings.

The import duty for conventional fluorescent lamps is fixed at five per cent of the value while the compact fluorescent lamps (CFLs) carry a 30% duty. An immediate priority action that can be taken by the Government is to totally abolish the duty on fluorescent lamps, both conventional and compact. This should allow the lowest possible cost of these lamps to prevail in the market. The cost of these lamps are of importance, especially at a time when there is rapid depreciation of the value of the Sri Lankan rupee against the US dollar and when there is high inflation (over 10% per year) in the country.

A further issue that requires detailed study and follow-up action is the electricity tariff structure. While the electricity tariff structure in Sri Lanka is guided by long run marginal cost considerations, the low consuming group up to 100 kWh/month receives electricity at a subsidized price as follows (the average price of electricity is Rs 2.40/kWh):

- up to 10 kWh/month at SL Rs 0.55/kWh;
- next 40 kWh/month at SL Rs 1.05/kWh;
- next 50 kWh/month at SL Rs 2.00/kWh;
- next 350 kWh/month at SL Rs 3.00/kWh; and
- further use at SL Rs 4.00/kWh.

Household electricity consumers, using less than 100 kWh/month, receive electricity at a subsidized price, well below the average selling price of SL Rs 2.40/kWh achieved in 1991 for the entire utility. The average tariff too does not exactly reflect the true cost of electricity. However, it can be used as an indicator of the finances required to retain the financial viability of the utility.

The majority of the household consumers consume below 100 kWh/month and hence they are subsidized (by the other electricity consumers). The important factor is that these very consumers, who receive electricity at subsidized rates, are those responsible for the high evening lighting peak and all the consequences thereby.

3.5 Replacement options

In formulating a programme for the widespread use of energy efficient lamps, the following replacement options have to be considered:

(i) the replacement of incandescent lamps with conventional fluorescent ones;
(ii) the replacement of conventional fluorescent lamps with high efficiency fluorescent ones and fittings, including CFLs; and
(iii) the replacement of incandescent lamps with high efficiency fluorescent fittings and CFLs.

The country has very little experience in the use of high efficiency fluorescent lamps, especially with CFLs. Technical issues related to the operation of such lamps, with regard to the voltage and frequency effects, and the widespread effects one in the existing system, require further study. Views have been expressed as to whether a component system—where the ballast, starter, and the high efficacy bulb are individually replaceable—would be more suitable than a compact fitting.

3.6 Model for the popularization of efficient systems

The manner in which efficient lamps and fittings should be popularized further in the efforts to improve the efficiency of electricity use, thus reducing GHGs emissions, has been under discussion for some time. It has been recognized that widespread use of efficient lamps in the households would require financial assistance for the consumers to meet the initial cost of the lamps and fittings.

3.6.1 A state sponsored programme

An option for the state utility would be to distribute free CFLs to households, in an effort to strongly carry the message of their high efficacy. If a 40 W incandescent lamp is replaced with an 11 W CFL, the 120 MW demand estimated in the earlier section would reduce to 33 MW and 95 GWh/year would be saved. Generating capacity is not a constraint in the Sri Lankan system as yet because the system carries a high reserve margin. The energy saved is valued at Rs 228 million per year (i.e., at 1991 average tariff of Rs 2.40/kWh). From the utility's point of view, the costs and benefits are given below, assuming consumers save on their marginal units which are usually paid for at Rs 1.05/kWh,

- Present subsidy to household—131 GWh/year × (2.40 − 1.05) Rs/kWh = Rs 177 million/year.
- Subsidy after the installation of CFLs—36 GWh/year × (2.40 − 1.05) Rs/year = Rs 49 million/year.
- Subsidy saved—177 − 49 = Rs 128 million/year.
- Number of lamps required—3 million; market price of a lamp—Rs 600; and total cost = 3 × 600 = Rs 1800 million.

Thus, for an entirely utility sponsored programme, Rs 1800 million is required for investment, saving thus Rs 128 million/year of subsidy to households. This however makes such an investment unattractive to the utility, showing a payback period of 14 years. Duty free import of lamps too would cost about Rs 400 each and the payback period would then be nine years. The reduction in peak demand has to be shown in order for the cancellation of a new power station, and to further justify such an investment. This issue will arise only after about the year 2000 AD, when the reserve margins of the system are expected to fall to international norms of 20-30%. The 87 MW of the reduced peak demand can be assumed, to avoid the investment on a gas turbine with a capital cost of Rs 1914 million, which clearly indicates the viability of investing Rs 1200 million in a CFL programme at that time.

However, a free CFL distribution programme does not appear to be viable now for the utility, unless heavily supported by the government and external funding agencies. A further justification for the use of CFLs would be the reduction of GHG emissions, by the expected saving of 95 GWh/year, which under average hydrological conditions, would be marginal units generated from thermal sources. The thermal source presently earmarked to meet this demand are residual oil fired diesel engines.

A further option is for the lamps to be distributed on loan, to be recovered in instalments on an interest free basis. Assume a household purchasing 3 × 11 W lamps:

- cost of lamps = 3 × Rs 400 = Rs 1200;
- energy saved = (40 − 11) W × 3 × 3 hours/day × 365 = 95 kWh;
- cost saved = 95 × 1.05 = Rs 100/year; and
- consumer's payback period = 12 years.

This payback period is often unacceptable to a consumer. However, the payback duration will change for consumers in the higher monthly consumption blocks, whose marginal kWh is paid for at the rate of either three or four rupees, but such households are only a small part of the total.

The above options clearly indicate that a CFL programme, fully paid for by the utility or by the consumers, would not be viable under the present generating system configuration and the consumers' tariff structure. The lifeline rates for lower income consumers are likely to remain for some time and the system load factor is likely to remain low, as long as the greater emphasis in system expansion is placed on rural household electrification.

There are also the possible weaknesses in a state/utility-run implementation programme. The utility is continuously engaged in the expansion and rehabilitation of the distribution network and handling day-to-day consumer services. The time available for the regular field staff to provide and monitor the use of CFLs in the households would be limited.

3.6.2 Private sector projects

A private sector project to handle the popularization of CFL is another option but, at the outset, it has to be clear that government or donor funding should be made available to launch the project. The

subsidy may be arranged in terms of the number of bulbs sold, where the consumer returns a confirmation note to the government/utility about the receipt of the lamp. A private organization, with a strong engineering and marketing background and its own dealer network, would be better placed to promote the use of CFLs, provide field level support, and monitor their use than a state utility. Adequate safeguards have to be built-in to protect the investment of the state/donor in the project together with back-up monitoring by the utility/donor.

3.7 Conclusion

The problems to be solved in the use of efficient lighting systems, with one of the objectives being the reduction of GHG emissions, are not strictly related to technology transfer but with the dissemination of the technology that is already available. The barriers to overcome are the high capital costs and the technical performance of efficient lighting systems, on one hand, and the subsidized household tariffs that make the critical component of system demand insensitive to the financial benefits of efficient lighting systems on the other.

Appendix

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Analytical framework of technology transfer

In discussing the transfer of technology, it is important to have a clear conception of what the term 'technology' means. Essentially, technology is information. The set of information that can be classified as technology is the one that describes human knowledge on the creation of systems. As such, technology can be viewed as a section of scientific knowledge that concerns the creation of things, as distinct from the other section of scientific knowledge—science. Science is concerned with the description and explanation about the structure and behaviour of systems, either natural or human-institutionalized. The contents of this set of technological information are growing dynamically, in keeping with the dynamics of human endeavours for the creation of things.

When the concept of technology is operationalized, it requires functional systems. Such systems can be more appropriately called technological phenomena. Technological phenomena can occur in various forms—physical functional systems, organizational systems and practices, and prescriptive informational systems that include design drawings, operating manuals, management techniques, material specification, and work procedures. It can also be extended to include individual skills and expertise on technological matters.

All these technological phenomena, however, are the carriers of technology. The Asian and Pacific Center for Transfer of Technology, of the Economic and Social Commission for the Asia and Pacific, grouped the information content of these various technological phenomena into four categories, namely:

- object embodied technology, designated as *technoware*;
- person embodied technology, designated as *humanware*;
- document embodied technology, designated as *infoware*; and
- institution embodied technology, designated as *orgaware*.

Based on these concepts of technology, transfer of technology is essentially transfer of information on human creativity in producing functional entities, that takes place among and through institutions. This may result in the generation of working arrangements that is considered useful in the support of human activities. These information transfers can have physical entities, such as capital

goods or individuals, data like engineering drawings, or institutional working arrangements like corporates.

The underlying problem that arises in relation to the earlier mentioned technological information flow basically stems from the fact that: (i) the information transferred is a valuable one, embodied in systems or prescribing systems capable of creating benefit or wealth, and influencing societal behaviour, and (ii) the effort to generate the information and the process of its embodiment into functional entities requires a certain amount of allocation of resources (human, material, and funds).

It is natural that the compilers of this information expect compensation for the resources spent to compile and package the information, and also certain rewards for the effect that the functionalization of the information can have in creating benefit or wealth. It is therefore apparent that, in spite of other considerations, the key issue to be realized in dealing with technology transfer is that it is basically a process of exchange where information is being traded directly. If the information trading occurs indirectly—when the information is already embodied in physical objects, the mechanism and institution of exchange is well-established and well-known. One can see such indirect information trade as commodity trade, where whatever problems that originally might have developed in the past have already been resolved. Such an established mechanism and institution for direct information trade is yet to evolve.

Besides the considerable shortage of established mechanism and institution, technology transfer processes have additional problems also. There are certain peculiarities about the actual technology transfer process. The following points illustrate some of these peculiarities.

(i) Technology, by its very nature, has the potential to induce change in productivity. This, in turn, could affect cost of production, competitiveness, or economic gains of the buyer. Furthermore, it may also induce innovative processes that may lead to the development of the capability of the buyer to the particular technology, or generate other technologies. This may run counter to the interests of the provider/producer of the technology.

(ii) Since the essence of technology is information, and information acquisition is attractive only when the party that tries to acquire the information does not completely master the subject matter contained in the information, the technology buyer has to face the risks of not getting what he really wants. On the other hand, the seller would not release the essential information, as then the commercial attractiveness will be lost.

Having elaborated on the essential nature of technology and transfer of technology, its core, i.e. analytical framework, which will be taken as a frame of reference for analysis in this study, has been developed and outlined below.

THE STRUCTURE OF THE TECHNOLOGY INSTITUTION SYSTEM

The structure of systems, wherein technology transfer processes take place, has some generic features. Figure 1 delineates the generic features of systems in which processes of innovation, that lead

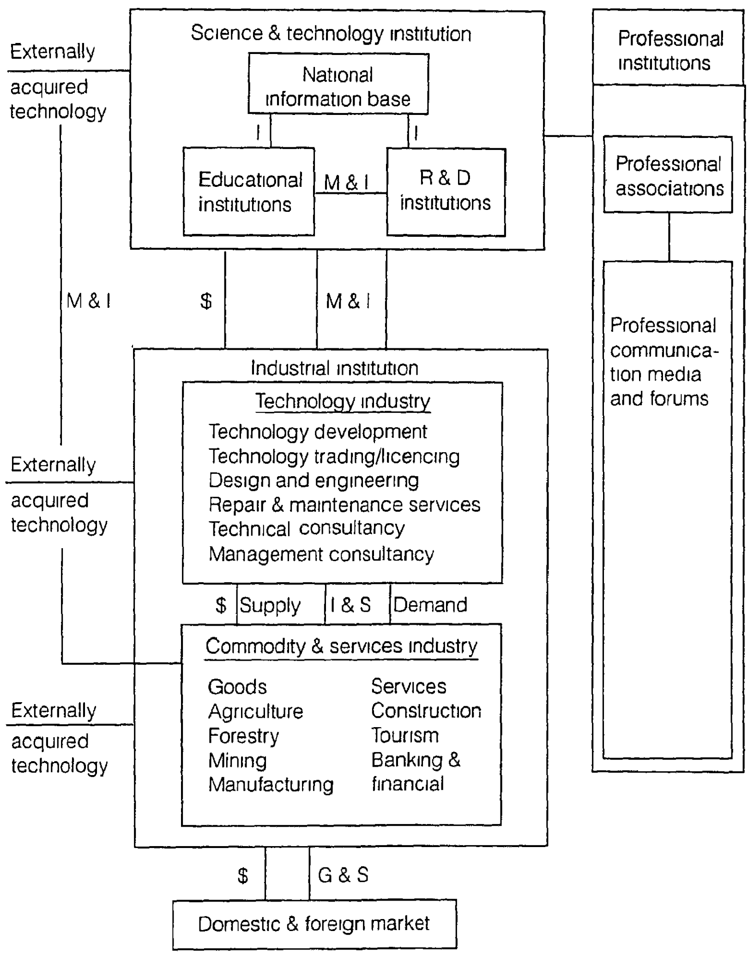


Figure 1. Schematic representation of innovation processes system. $—money; M—man power; I—information; S—services, and G—goods

to the functioning of technological systems, in productive activities take place. Transfer of technology takes place within and through the various elements of that structure.

As can be seen in Figure 1, the basic elements that accommodate and motivate innovative processes are science and technology (S & T), professional, and industrial institutions, and the market. Except the market, all of the other elements are directly involved in the technology transfer processes.

The industrial institution has two distinct components—the technology industry and the commodity and services industry. The first stands for that component which translates and packages R & D results in S & T into technological prescriptions that can be operationalized in the production and delivery of goods and services found in the commodity and services industry. The latter is that part of the industrial system concerned with the production and delivery of goods or services, but does not generate the goods or services delivered to the market.

Thus, the technology industry is the key element in the structure which determines the technological capability of the system, as it is here that information is processed into prescriptive informational packages that are useful and implementable in production activities.

Patterns of technology transfer

Technological transfer can originate from the internal or external sources. That transfer which originates from external sources is part of the international transfer of technology process. With respect to the system under consideration, such transfer is designated as horizontal transfer as the direction of the externally acquired technology flow is a horizontal one. The transfer of technology originating from internal sources, as drawn in Figure 1, basically flows in the vertical direction and is, therefore, designated as vertical transfer. For internally generated technology, innovations that lead to the generation of technology could take place in any of the elements of the indicated structure. However, the flow will always be one.

Externally acquired technology

In the case of the externally acquired technology, the entry point could be at any level. However, the dominant technological components acquired are different for each entry point. The costs involved are also significantly different. If the transaction occurs at the S & T and professional institutions level, the dominant components transferred are *humanware* and *infoware*, and mostly involves open information. The cost consequences of the transfer are the lowest when compared to those entering the other element—the industry institution. However, the outcome of follow-on activities that will eventually result in productive commercial operation is uncertain and undetermined.

The transactions which take place at the industrial institution level can have two different entry points—the technology industry or to the commodity and services industry. If the entry point is at the technology industry level, the technological components being transferred are dominated by *humanware* and *infoware*, as in the case with the transactions taking place in the S & T and professional institutions. But, in addition, it can also include a substantial transfer of *orgawares*. Furthermore, the costs are considerably higher. The effectiveness of the transfer, as measured by the quality and intensity of subsequent transfer to the commodity and services industry, is predominantly governed by the recipient of the technological capability. The flow of externally acquired technology to the commodity and services industry is generally very costly, and is dominated by *technowares* and *orgawares*. The technological deficiency of a nation can be traced by the high proportion of externally acquired technology at this entry point.

In most of the developing countries, this type of transfer generally leads to the other transfer mechanisms. Some of the main reasons are listed below.

(i) In the process of industrial development, the pressing need is for the supply of basic goods and services to set the industry in motion. Technology acquisition is, therefore, the purchase of capital goods.

(ii) There is generally lack of technological capability to cope with the more sophisticated or less ready-to-operate type of technological forms; e.g., capital goods *versus* equipment drawings.
(iii) The transfer is preferable to investors, either domestic or foreign, because from any investor's point of view the motivation for capital investment is certainly not technology transfer, but the capturing market opportunity and securing market shares of their products.
(iv) Considerations, concerning the scarcity of capital and technological resources, the investment risks, and the gestation time for the effective delivery of the services that the technology, are expected to offer make the transfer more appealing.

Once the technology is transferred and put into operation, the path to support these systems, like repair, maintenance, and technical advice, will be open. The demand for such supporting systems will induce business opportunities and ventures in technical services that are within the realm of what was previously designated as technology industry. Otherwise, the situation will motivate such endeavours through different channels, such as government initiated establishment or enterprises, or through the imposition of regulations that force the establishments of the above mentioned technical services. Eventually, it may lead to the development of design and engineering as well as internally generated technological prescriptions, either on newly developed technology or on the improvement or adaptation of the externally acquired technology.

Internally generated technology

Technology transfer processes, involving internally generated technological systems, can be seen as a separate process parallel to those involved in externally acquired technology, or else can be considered as part of the overall transfer process.

As one considers many interacting systems, each with a structure as described in Figure 1, the second point of view is more appropriate. Processes within each structural system boundaries can be considered as part of the overall transfer process among the interacting systems. The system boundaries may coincide with national or corporate boundaries, or other entities carrying such technology to an institutional structure.

Transfer processes among the systems mainly contain information flow processes through various exchange mechanisms. The processes taking place inside the boundaries of each system comprise many process elements, that include decisional processes concerning the allocation and exchange of resources related to technology development or technology acquisition, processes for technology marketing, dissemination for acquisition, and processes that directly deal with the development, maintenance, and operation of the technology.

Concerning the last group of processes—technology development, maintenance, and operation—if a particular technology originates from sources outside the system boundaries, the terms that are listed below are often used.

(i) 'Adoption', if the technology, upon acquisition, is to function as received.

(ii) 'Absorption', if, in the course of operating the technology, increasing comprehension and mastery of the technology takes place.
(iii) 'Adaptation', if modified to make the technology more suitable to the environment where it is to function.

When adaptation and absorption take place, further effects, leading to the stimulation of technology development in areas around the acquired technology, may occur. The confidence that results with the development activities may also stimulate the development of other technologies.

Mechanism of transfer of technology

Figure 2 provides a visualization of the structure of the mechanisms of the previously described processes. It shows that there are basic elements to be considered in analysing transfer of externally acquired technology—the technology being transferred (T), the medium that carries the technology (M), the channel for the transfer (C), the source of the technology (S), the recipient of the technology (R), and the environment in which the transfer processes take place.

The terms previously mentioned will be clarified further. Technology component is the particular technology being transferred; in this particular study, the technology in question is cogeneration technology. The medium is the carrier of that technology and includes capital goods, management and technical assistance contracts, training, documents, experts, or skilled persons. The transfer from the source to the recipient will take place through channels, like investments, and technical assistance or development aid programmes. The environment for technology transfer includes laws, regulations, procedures, business practices, general economic conditions, wages, and income levels as well as the level of technological capability of the work force, R & D institutions, and educational institutions. Policies on development, trade, energy, and other development sectors are also important elements that influence technology transfer processes.

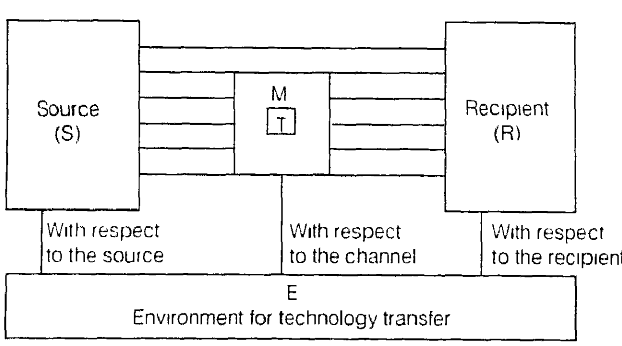


Figure 2. The structure of the basic elements in the mechanisms of transfer of technology. T—technology component; M—medium; C—channel, S—source; R—recipient, and E—environment.

Conclusion

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The creative infrastructure required for technology transfer includes the aggregate of scientific and engineering data, methods, processes, equipment, and systems along with financing, organization, and management to facilitate achievement of industrial or commercial objectives. Pursuit and development of such an infrastructure account for a large share of the economic activity of developed countries and are goals for developing countries.

It is worth noting that the current world energy infrastructure is a product of massive transfers of technology that have occurred since the Industrial Revolution (Gray 1984). However, the bulk of these flows took place in the western hemisphere and, as Myrdal (1981) points out, the technical innovations and technologies thus developed in the late eighteenth and early nineteenth centuries were rather simple mechanical kinds requiring less capital intensity. The situation is dramatically different today, when there is an inextricable link between technology and scientific knowledge, and from this arises the complexities attached to transferability of technologies, especially from the developed to developing countries. The dynamic process of scientific and technological advancements implies that developing countries not only have to adopt and adapt higher levels but have to also ensure a continuity of rapid and higher advancements. Further, given a different set of social, economic, and institutional milieu and factor endowments, the choice of an 'appropriate' technology is important. The former, of course, presumes a climate of lowered barriers and creation of more opportunities for technology transfer.

The debate on technology transfer has acquired a new dimension in light of the recent negotiations on climate change. According to Lee and Kim, ownership of technology lends a competitive advantage to the owners in appropriating the world resources; in the role of technology transfer in promoting harmony on a global scale; and through that in achieving equalized development and preventing global warming, is an intent only on paper. Further, they stress the need to guard against 'relocation' rather than 'transfer' of technology, which will exacerbate the technological dependency of the South. Emphasizing on capacity building, they suggest that a successful technology transfer occurs when the recipient country has evolved the indigenous capability to acquire, assimilate, utilize, diffuse, and institutionalize imported technology into the development process, as exemplified by the

case of Korea. The indigenization of foreign technology was carried out in a partnership model integrating the state, public corporations, R & D institutes, and industrial conglomerates. Further, the industrial conglomerates or 'chaebols' internalized technological innovation by establishing and expanding their research institutions (even though it was for short-term commercial possibilities rather than environmentally sound and energy efficient technologies). Regarding the specific case of Korea, installation of cogeneration plants in the industrial sector has been facilitated by the Government since 1980s, through financing and legal reforms. However, government support is not directed chiefly at indigenization but at circumventing the financial, environmental, and spatial constraints for large power plants. The latter promotes turnkey projects, thus hampering the domestic industry's efforts to indigenize the technology. Transfer and development of this technology (except the core component of turbines) have been at the initiative of domestic corporations, such as the Hyundai Heavy Industry.

In Indonesia, the choice for cogeneration systems in industry was not a deliberate one, rather it was acquired by default as a part of the technology package for the entire plant (e.g. the chemical industry). The exceptions are agro-based industries, such as the palm oil and sugar industry, in which the practice was introduced in the colonial era. However, in recent years, industries, like the plywood and the wood products industry in which cogeneration is a good option, did not take it up. This lack of appreciation is attributed to inadequate information dissemination as well as availability of low priced refinery products. Sasmojo *et al.* indicate that while the policy on energy is, in general, supportive of ventures that would improve the efficiency of the economy, the policies relating to capital financing, taxation, imports duties, and, most importantly, energy pricing are not adequately tuned to effect such changes.

In contrast to the Indonesian case, in Thailand, the Government is promoting energy conservation very seriously since 1991 through legislative instruments. The energy conservation law has been changed to provide incentives to the private sector to conserve energy and funds have been allotted by the Government to provide financial assistance to deserving projects. In this facilitating climate of capital financing, tax incentives, and appropriate duty structure and assurance of selling excess power to the grid at fair prices, the private sector has built its capability in acquiring technologies from abroad. As far as absorption of this technology is concerned, the large enterprises have done so effectively since 1974, when the first cogeneration system was installed. Regarding the indigenous development of this technology, Boonyubol and Chamchoy, analyse that, since the size of the domestic market is so small, it is not economically feasible for such an energy facility industry to set root. The case for energy efficient lighting is also promising in light of the recent programme for demand-side management. There are no barriers to acquiring the technologies and, in this industry too, the private entrepreneurs have adequate skills and contacts with foreign firms. The only obstacle is the high initial costs and consumers' reluctance to incur them.

The obstacle to introducing efficient lighting in Brazil, in contrast, is more due to the structure of this industry. The dominant lamp manufacturers include multinationals such as Philips, Silvania, General Electric, and Osram. This cartel is protected against imports and thus has no incentive to

produce more efficient illumination systems. This is exemplified by their response to the national programme called Electricity Conservation Programme (PROCEL), directed at removing barriers to efficiency improvements. Under this programme, the manufacturers of better systems were given the privilege of free marketing, to enable higher sales in the short and medium term, and thereby reducing unit costs. The cartel's response to this initiative was to increase prices in order to maximize profits. The low awareness about the new and efficient systems, results in a small market, and the high cost–high price–small market triangle has consistently limited penetration of the relevant technologies. The interest in cogeneration technology is of a recent origin and, according to Moreira *et al.*, has been stimulated by lack of capital for expanding the supply of electricity. The Secretariat of Science and Technology has expressed faith in cogeneration systems using natural gas. However, the institutional issues like guarantees for minimum load factors and prices paid by utilities have to be resolved to stimulate the use of this technology in Brazil. Even under the current adverse deal the sugarcane and ethanol industry are selling excess electricity to the grid.

While the extent of conservation potential through total energy systems is well appreciated in India, and the fact that an Inter-ministerial Working Group on energy conservation had estimated an economic potential of about 1500 MW through cogeneration as far back as 1983, the adoption by the industries has been limited. The technological reasons for this are inadequate availability of high pressure boilers, turbines, and accessories. Secondly, the industries find it difficult to raise resources for the incremental cost of setting up a cogeneration system, given the tax and duty structure for capital equipment. Further, the lack of a framework, for wheeling and banking of cogenerated power and pricing, serves as a deterrent. In the context of technology transfer, the menu available in India is quite good, although it will be useful to acquire certain advanced systems. In the area of efficient lighting, the manufacturers interviewed for this study indicated that some compact fluorescent lamps (CFLs) were being imported and companies, such as Philips, Osram, General Electric, and Phoenix Electric, are willing to give the technology to their Indian counterparts. However the prevailing duties on equipment were too high. Further, the consumer is averse to the idea of high initial costs (regardless of the low operating costs and payback periods) and this restricts the volume of the market, resulting in a reluctance to manufacture them. Some manufacturers have taken the decision to manufacture CFLs in the export processing zones where they can avail of the concessional duties structure. But bulk of their production will be earmarked for export. Hence, the problem is that of absorption of this technology. Institutional push and consumer awareness are also critical for both these technologies.

According to Omar and Hossain, in Bangladesh, studies and initiatives for technology transfer are limited to declarations of intent without any supportive operational mechanisms. The 1985 document on the 'National Science and Technology Policy committee' had emphasized the 'establishment of a national capability for development of indigenous technology and attainment of national capacity for the assessment, selection, acquisition, adoption and adaptation of foreign technology'. However, nothing tangible has been done in this regard until now. In fact, new and varied technologies have been implanted in Bangladesh, more representative of a static mode of transfer. As far as the case-

study for cogeneration is concerned, industries like the fertilizer, sugar, and paper industries have such systems. However, the greatest potential is in the jute and textile sector. These sectors are either incurring losses or are only marginally profitable, which prevents the local banks from disbursing soft loans obtained from the World Bank.

From the foregoing discussion, it is obvious that technology transfer is not a 'quick fix' which can provide a nation with self-reliance in energy supply and use matters. It has to be attended with clear guidelines which facilitate the acquisition of the technology, appropriate legal and administrative framework for wider dissemination, and institutions and R & D to indigenize the technology and produce it. This, of course, requires human skills and capability building to make the right choices and implement them. It has also been referred to by Takao Tomitate, that it is not essential to transfer the state-of-the-art technology but that which is best fit to prevalent conditions in developing countries. Reflecting a donors point of view, he has emphasized the need to strengthen planning in energy and technology to commensurate with economic plans, culture, and climate in developing countries. This is best illustrated by the Korean experience. Initially relying on foreign technology and capital, the state, public and private corporations partnership adopted a planning structure that helped in indigenization of technological development.

REFERENCES

1 ADB. 1990. Industrial technology capabilities and policies in selected Asian developing countries. ADB Economic Staff Paper 46. Manila: Asian Development Bank.
2 Myrdal G. 1981. The transfer of technology to underdeveloped countries. *In* Kuehen T J, Porter A J (eds). *Science, Technology and National Policy*. Ithaca and London: Cornell University Press. 215–225.
3 Gray J E. 1984. International energy technology transfer. *In* Kursuenoglu B N, Perlmutter A, Scott L (eds). *Global Energy Assessment and Outlook* London: Harwood Academic Publishers. 541–546.
4 von Moltke K. 1992. International trade, technology transfer and climate change. In Mıntzer I M. Confronting Climate Change—risks, implications and responses. Cambridge: Cambridge University Press. 295–304.